AD-A181 712 COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT A CASE PROJECT STUDY (U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS INFOR D RAISANEN 1/1

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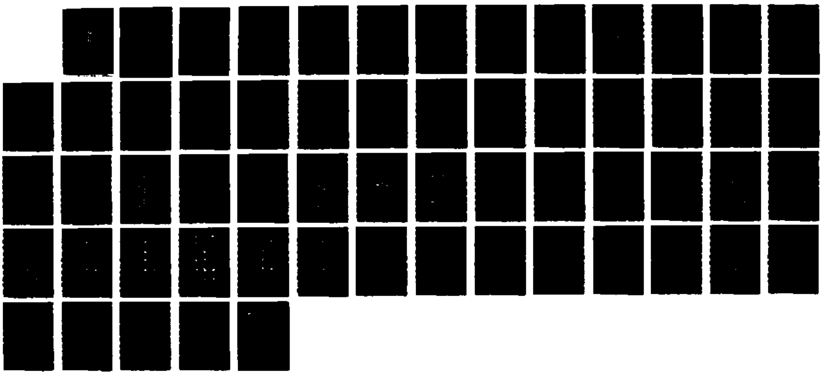

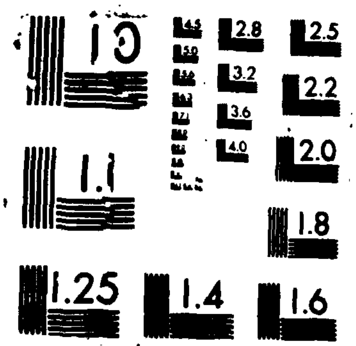
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Computer-aided design
Concrete slabs
Flooring, Concrete
Finite element method
GTSTRUDL (Computer program)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a study aimed at providing guidance for the use of finite element analysis programs. As part of the Computer-Aided Structural Engineering (CASE) Committee study, it focuses on techniques for concrete flat slabs. With a purpose of developing criteria for finite element analysis of flat slab floors, this report has two objectives. To compare methods for the most acceptable yield and to apply these guidelines to the active design problem
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20. ABSTRACT (Continued)

requires that this report include element selection, initial assumptions, comparisons of verification study, results, discussion of results, conclusions, and recommendations using the finite element methods. A powerhouse erection bay floor slab was selected for the problem solutions, with the GTSTRUDL program's "IPBQQ" element the only one suited to this problem.

PREFACE

This report is aimed at providing guidance for the use of the finite element method of analysis for the design/analysis of concrete floor slabs. The work was sponsored under funds provided to the US Army Engineer Waterways Experiment Station (WES) by the Civil Works Directorate, Office, Chief of Engineers (OCE), US Army, as part of the Computer-Aided Structural Engineering (CASE) Project.

Input for the report was obtained from the CASE Task Group on the Finite Element Analysis. Members and others who directly contributed to the report were:

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Dick Huff, Kansas City District
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Jerry Foster, Federal Energy & Regulatory Commission
Ed Alling, USDA - Soil Conservation Service
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The report was compiled and written by Mr. David Raisanen. Dr. Radhakrishnan, Chief, Information Technology Laboratory (ITL), WES, and CASE Project Manager, along with Dr. Robert Hall, Research Civil Engineer, ITL, WES, and H. Wayne Jones, Civil Engineer, ITL, WES, monitored the work. This report was edited by Ms. Gilda Shurden, Information Products Division, ITL, WES, with Ms. Frances Williams coordinating text and figure layout. Mr. Lucian Guthrie, Structures Branch, Civil Works Directorate, was the OCE point of contact.

COL Allen F. Grum, USA, was the previous Director of WES. Col Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
kip-feet	1355.818	newton-metres
kips (force) per square foot	47.88026	kilopascals
kip-inches	112.9848	newton-metres
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals

A CASE PROJECT STUDY OF FINITE ELEMENT ANALYSIS OF CONCRETE FLAT SLABS

PART I: INTRODUCTION

Background

1. This study has been prepared as part of the Computer-Aided Structural Engineering (CASE) Project study of finite element analysis techniques for concrete flat slabs. It is part of a Corps-wide program to provide guidance for the use of finite element analysis programs.

2. Information contained in this report is based on results from a study developed in 1983 by the CASE Finite Element Methods (FEM) Task Group. Flat slabs with large openings present a common design problem for the Corps, and standard analysis procedures do not adequately cover the effects of these openings. This study also investigated the effects of including the contribution of shear to the transverse deflections of the slab by including an element which could adequately capture this behavior. The problem selected for study is a concrete floor slab in a powerhouse erection bay and the above problem areas are included in the investigation along with corresponding illustrations. Plan and elevation views are shown in Figures 1a and 1b. The slab has overall dimensions of 123 by 76 ft* and is 2 ft 9 in. thick. It is made of 3,000 psi concrete and is reinforced with 40 grade Rebars in both faces. There are two large hatchway openings which measure 27 by 20 ft. The floor is supported by walls on three sides and by three rows of interior columns on approximately 20-ft spacings. The main design load is a 1,000-psf uniformly distributed load.

Purpose

3. The purpose of the study reported herein is to develop finite element analysis criteria for flat slab floors in situations in which ordinary design methods will not suffice. These criteria will address modeling methods, deflections, and stresses.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

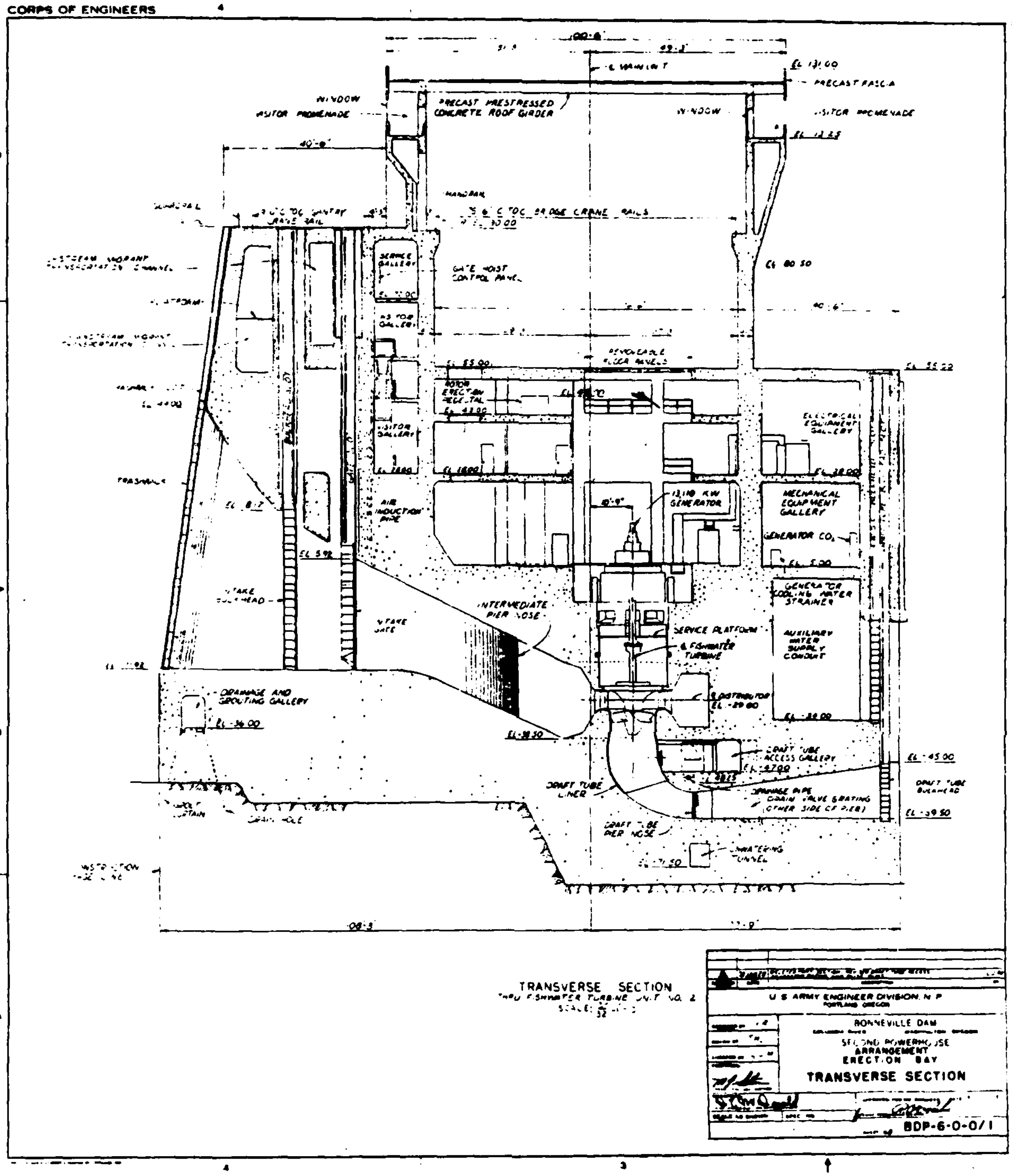


Figure 1a. Elevation view of powerhouse erection bay, concrete outline, transverse section

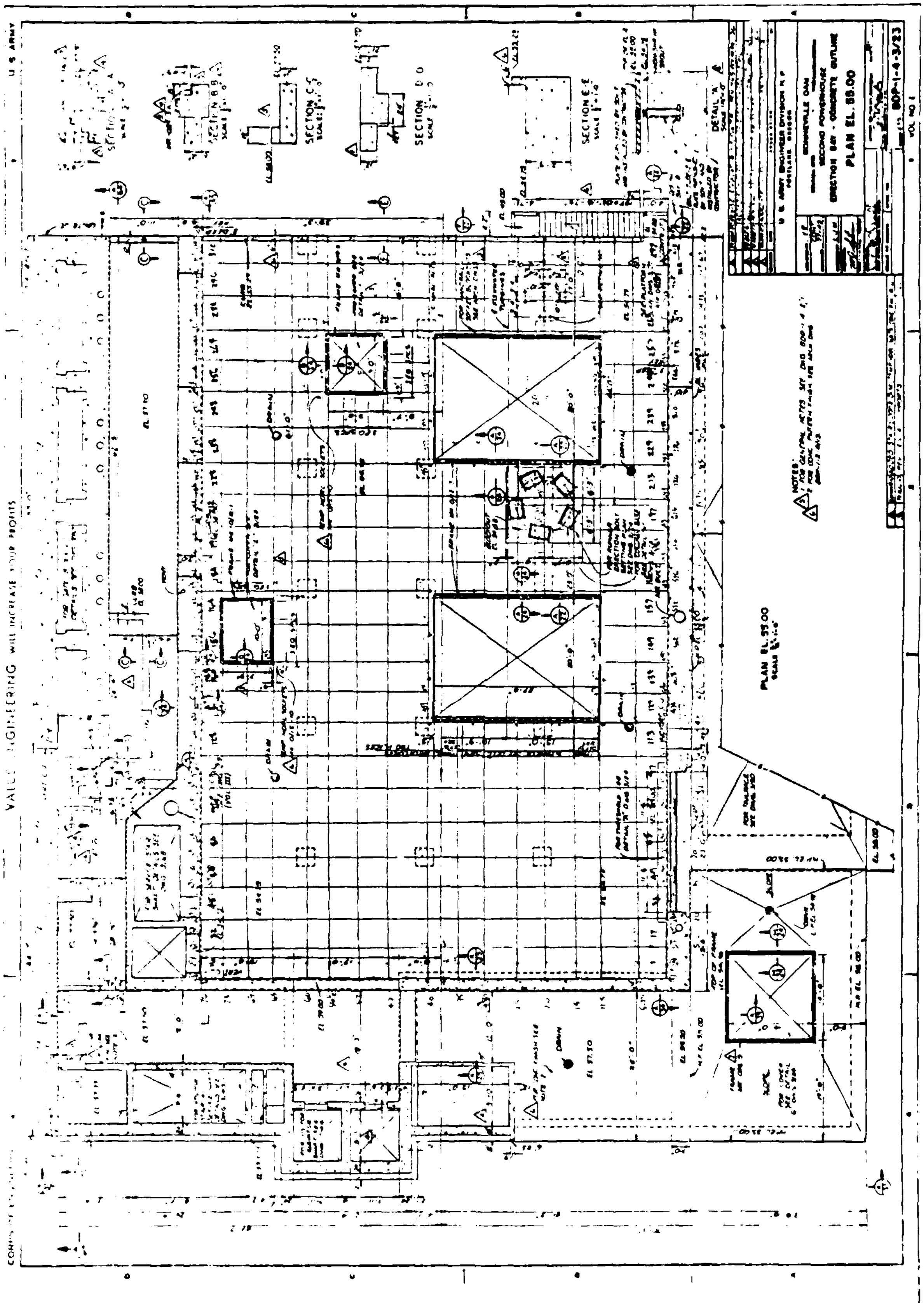


Figure 1b. Plan view of powerhouse erection bay, concrete outline, el 55.00

Objectives

4. This study has two objectives. The first objective is to compare FEM models with closed-form or other analytical methods to ensure that modeling techniques, mesh criteria, and element types will yield acceptable results for design. These results will then be used to develop guidelines for future analyses. The second objective is to analyze the above slab and to show how these guidelines are used in an actual analysis.

Scope

5. The scope of this study is to analyze deflections and stresses caused by the slab's dead load and a uniform live loading of 1,000 psf due to generator and turbine parts. Neither temperature and curing stresses nor interaction of the slab with the remainder of the structure will be analyzed. The following will be presented:

- a. Element selection.
- b. Initial assumptions.
- c. Comparisons of verification study with closed-form analysis.
- d. Results from FEM analysis of the slab problem.
- e. Discussion of FEM results of the slab problem.
- f. Conclusions and recommendations on analysis of flat slabs using FEM.

PART II: ELEMENT SELECTION

Criteria

6. Based on the requirements for a slab analysis, the following factors were considered in element selection:

a. It must be able to accommodate concentrated and uniform loading.

b. Output shall be displacements and stresses at nodal points.

c. Shearing deflection contributions shall be taken into account since the span/depth ratio of the slab is less than 10.

d. In-plane stresses will not be considered.

On the basis of the above criteria, the GTSTRUDL program has an element suited to the problem. The "IPBQQ" element will allow for shear deflection and bending deflection.

Problem Idealization

Verification study problems

7. Two finite element programs and two different elements were chosen for the verification study. The membrane element from E^3SAP was used to model plate-bending action without the shear deformation capability. The GTSTRUDL IPBQQ element was used to study the same problems, but including the effects of shear deformation. This verification study consisted of two problems. The first being a 20 by 20-ft slab (Figure 2a), simply supported along all edges and subjected to a uniform loading. This problem was analyzed by the use of four meshes: the first has 1 element, the second, 4, the third, 16, and the fourth, 64, each succeeding mesh being the result of dividing each element in the previous mesh into 4 equal elements (Figures 2b, 2c, 2d, and 2e). Only one fourth of the plate was modeled, allowing for symmetry. The second problem used the same meshes and loading, but was representative of an interior panel of a continuous slab supported at each corner by a column. The boundary conditions were modified to reflect this support condition.

Powerhouse slab study

8. The slab was modeled for both the E^3SAP and the GTSTRUDL analyses, with 16 elements per panel, as suggested by the verification study. The only difference in the these analyses was that the IPBQQ element of GTSTRUDL allows for shear deflections. Mesh refinement around reentrant corners was not done in the general model since an actual design would isolate these areas

with a smaller model for separate analyses. The slab was assumed fixed at all edges which were framing into walls. Supporting columns were modeled as "pin" supports. Figure 3 illustrates the three lines where results from the analysis were interpreted.

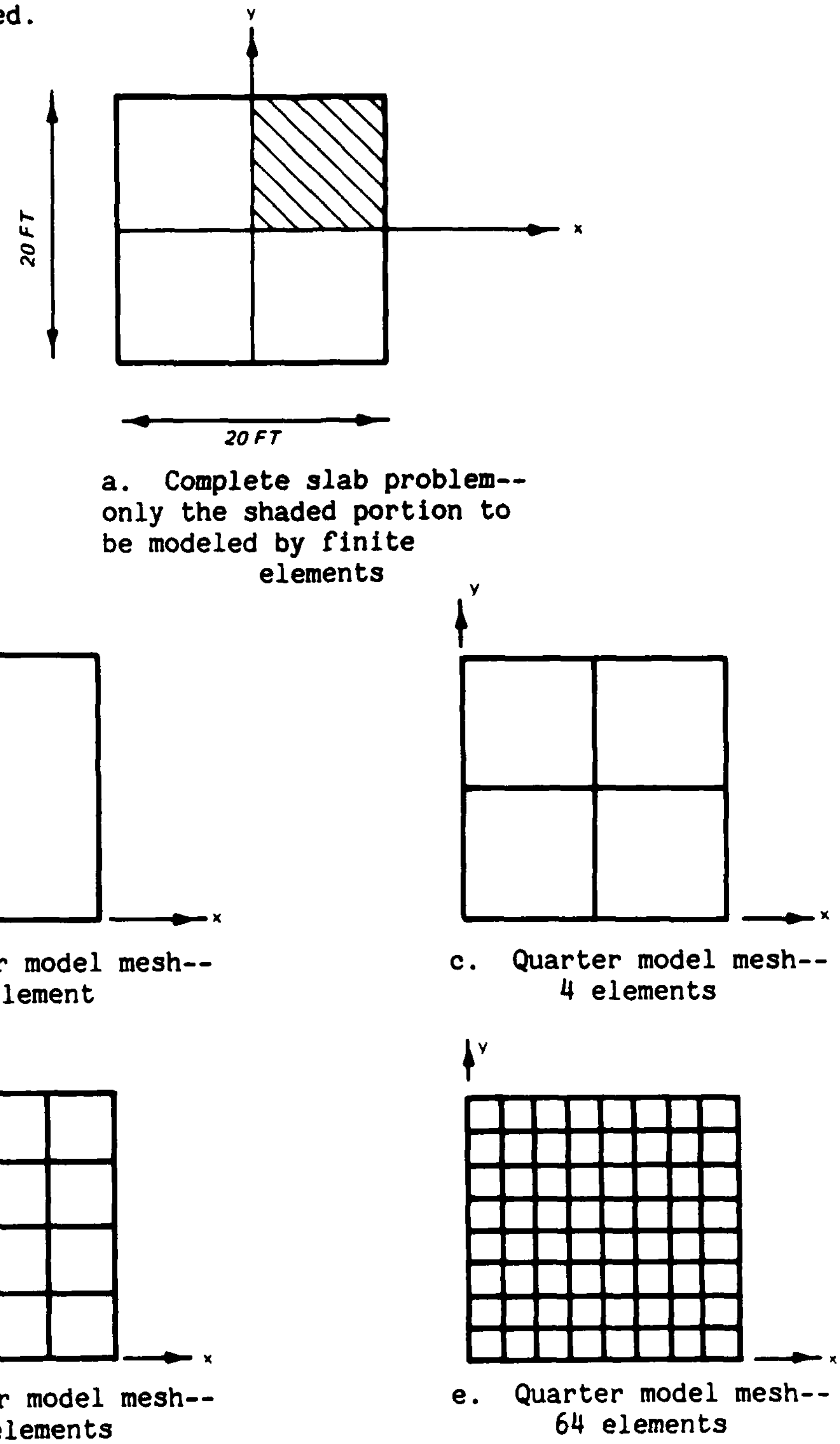


Figure 2. Meshes for slab verification study

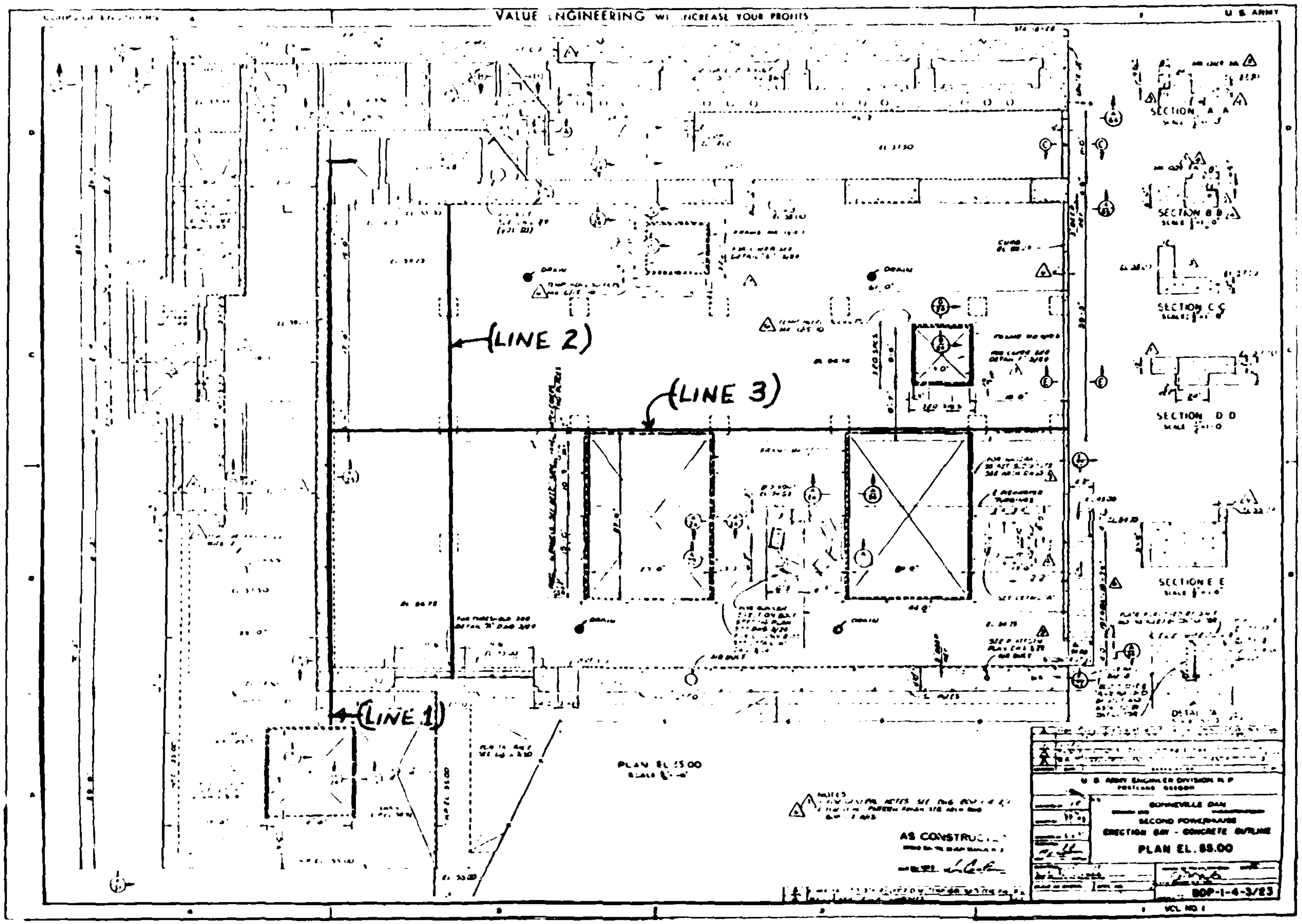


Figure 3. Plan view of powerhouse erection bay showing the three column lines on the slab along which interpretation of analysis results will take place

PART III: MODELING TECHNIQUES

E^3SAP Model

9. The verification study showed that acceptable results would be obtained with a mesh of 16 elements in each slab panel. This pattern was used in forming the meshes for the powerhouse slab. The slab was analyzed using the mesh shown in Figures 4a-4c. The TYPE 6 membrane element was used. This element requires four nodes per element. Element thickness is an input item. The boundary of the slab at wall intersections was modeled as a fixed-edge condition with all deflections and rotations set to zero. The nodes at interior columns and walls were allowed to rotate with the deflection still set to zero. Loading was set at 1,000 psf live load due to stacking of generator and turbine parts plus the slab dead load. Loading on the hatch covers was transferred as concentrated loads at the nodal points on the periphery of the hatch opening. Material properties were set at values corresponding to a concrete with f'_c , ultimate concrete strength, equal to 3,000 psi at 28 days.

GTSTRUDL Model

10. The slab was analyzed using the mesh shown in Figures 5a and 5b. It uses the IPBQQ element which requires eight nodes per element, four corner nodes plus four intermediate nodes along the sides. Element thickness is an input item. The verification study showed that this mesh would produce acceptable results. The problem was analyzed with two different sets of boundary conditions. For the first analysis, the boundary of the slab at the wall intersection was modeled as fixed with both rotations and deflections set to zero. Columns were handled the same as for the E^3SAP model described above. The second analysis modeled the walls and columns as springs with axial and moment stiffness coefficients. These coefficients were calculated from frame analysis runs made for a 1-ft strip of wall, representative of the wall configuration at the node in question. This run was made to provide a more accurate representation of the slab boundaries than could be provided by using the simplified pinned or fixed assumptions of the first analysis. The GTSTRUDL input files for both runs are shown in Appendix A.

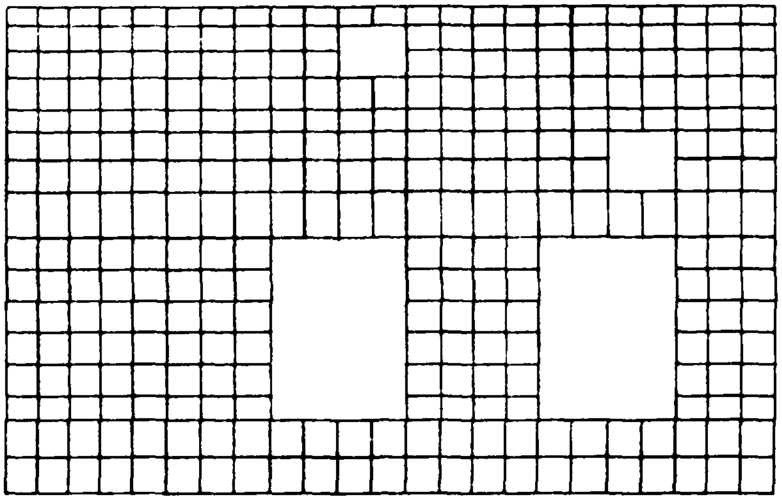


Figure 4a. Finite element mesh for running E^3SAP model

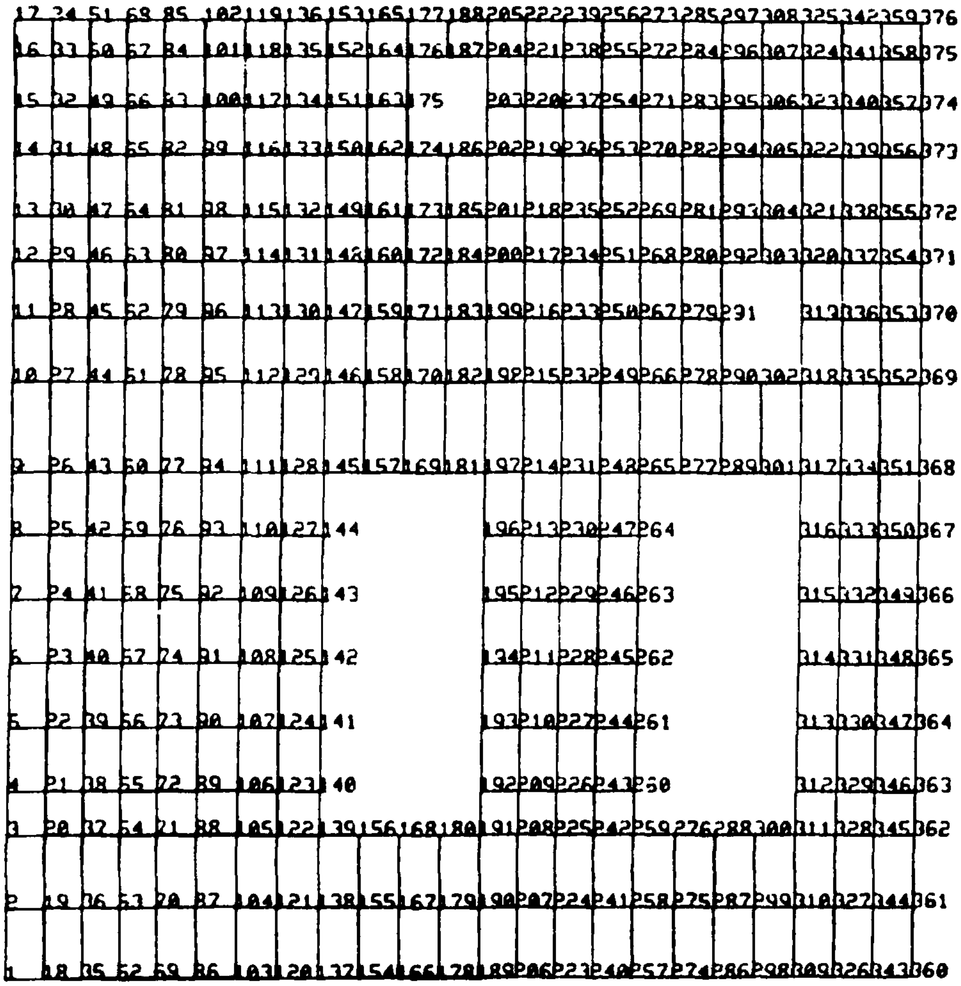


Figure 4b. Node numbering of mesh for running E^3SAP

Figure 4c. Element numbering of mesh for running E^3SAP model

Validity of Mesh

11. The mesh selected gave elements with a maximum aspect ratio of 1.83:1, well under a ratio of 4:1 which is suggested as a maximum based on past experience. This ratio allows for accurate results in both deformation and stress calculations. High stresses exist at reentrant corners in the actual slab, however this particular mesh is not refined in these areas. This mesh gives an approximation of moments sufficient for design, although the designers should bear in mind that a refined grid in areas of high stress gradient may be necessary for some problems.

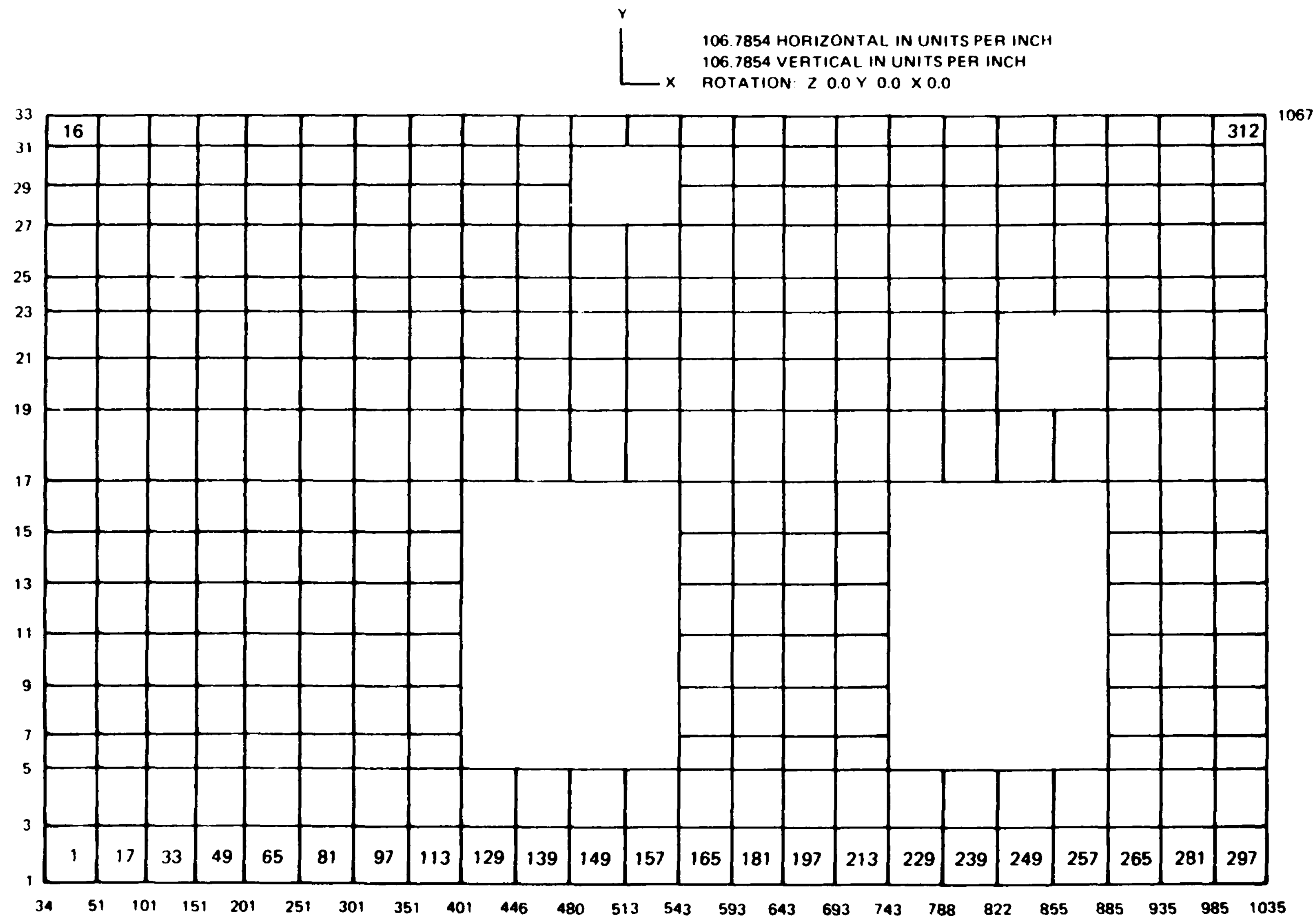


Figure 5a. Finite element mesh for running GTSTRUDL model, first view

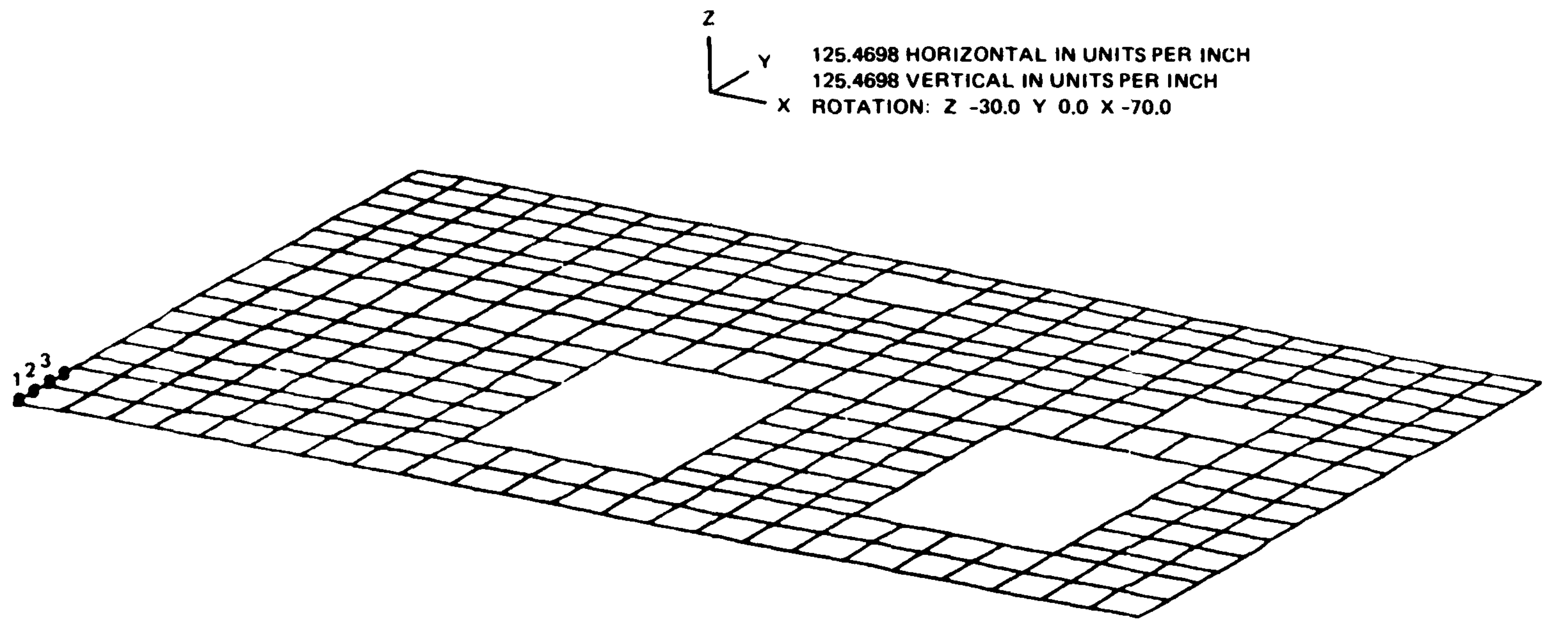


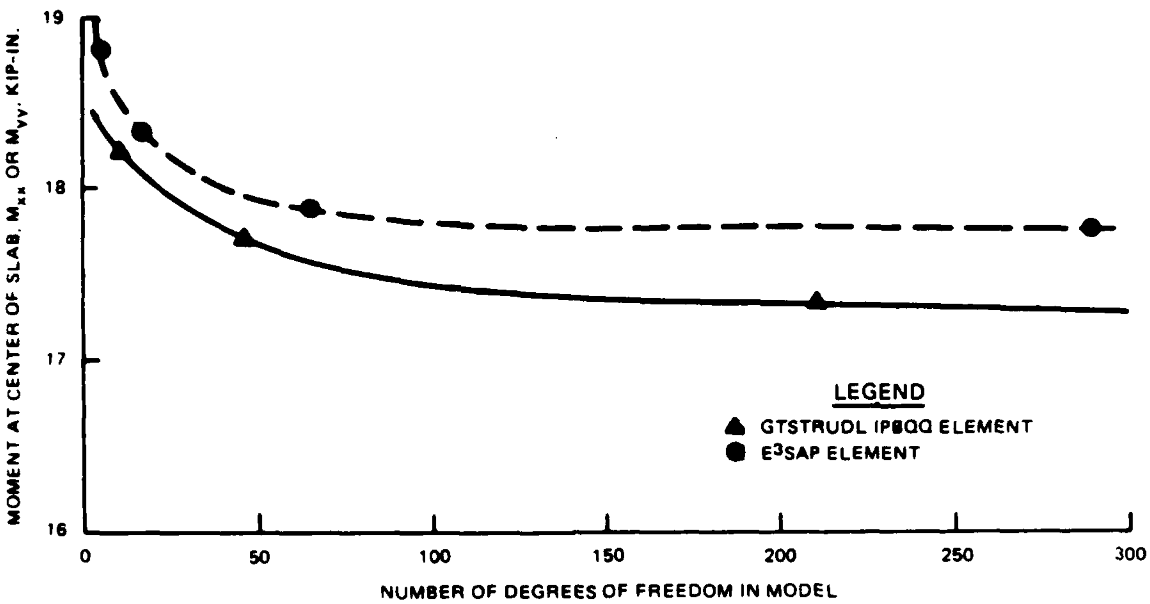
Figure 5b. Finite element mesh for running GTSTRUDL model, second view

PART IV: FINITE ELEMENT ANALYSIS RESULTS

12. Results from the GTSTRUDL and E^3SAP verification problem for a simply supported slab with a uniform load are shown in Figures 6a and 6b. The results for the fully fixed edge slab are shown in Figure 7. These results indicate that four elements are adequate for modeling one quarter of a square plate for either set of boundary conditions. The theoretical results for the simply supported plate are shown in Appendix B. Timoshenko's plate theory equation is shown with added coefficients to account for shear deformations. As seen from these results, the shear deformations are important and the GTSTRUDL element matches the theoretical results. A theoretical solution for the continuous slab was not available.

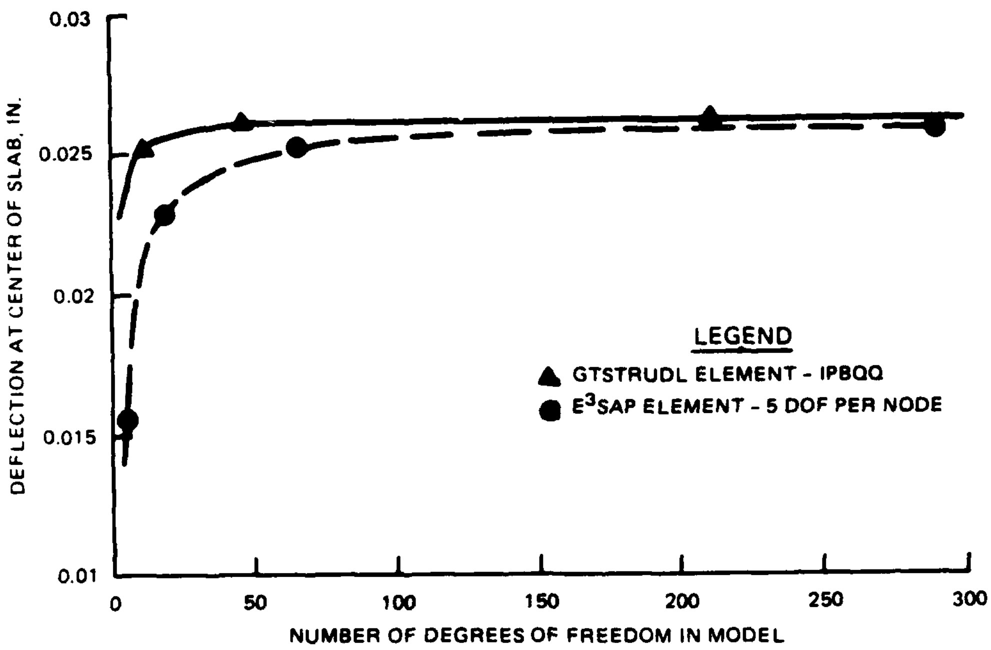
13. The powerhouse slab analysis with fixed edges was analyzed using the programs, E^3SAP and GTSTRUDL. Selected results and graphed comparisons for deflection and moments are shown in Figures 8 through 14b.

14. Selected results form the GTSTRUDL analysis using elastic springs to model the wall and column supports are compared with the GTSTRUDL fixed-support analysis in Figures 14c through 17. Figures 18 through 20 show the contour plots of the moments, M_{xx} , M_{yy} , and M_{xy} , respectively, for the GTSTRUDL analysis of the slab with fixed supports. Figures 21 through 23 show the contour plots of the moments, M_{xx} , M_{yy} , and M_{xy} , respectively, for the GTSTRUDL analysis of the slab with elastic spring supports. All runs were checked to ensure equilibrium of the model. All reactions were totaled and compared with the original loading conditions. The values for the spring constants were calculated by using a 1-ft strip model of the structure for each wall configuration with a moment applied at the slab support level. The Corps' CFRAME computer program was used for making the analysis of these 1-ft strips.



PROGRAM	NUMBER OF DEGREES OF FREEDOM IN MODEL							
	5	9	14	46	66	211	290	863
GTSTRUDL		18,215		17,708		17,341		17,263
E^3SAP	18,815		18,301		17,888		17,780	
	1 ELEMENT		4 ELEMENTS		16 ELEMENTS		64 ELEMENTS	

Figure 6a. Comparative graph and tabular recordings of moments at center of slab, M_{xx} or M_{yy}, from verification study using programs GTSTRUDL and E^3SAP for simply supported slab



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<tr><td>5</td><td>9</td><td>14</td><td>46</td><td>66</td><td>211</td><td>290</td><td>863</td></tr>
<tr><td>GTSTRUDL</td><td></td><td>0.0253</td><td></td><td>0.0262</td><td></td><td>0.0262</td><td></td><td>0.0262</td></tr>
<tr><td>E^3SAP</td><td>0.0155</td><td></td><td>0.0228</td><td></td><td>0.0252</td><td></td><td>0.0258</td><td></td></tr>
<tr><td></td><td colspan="2">1 ELEMENT</td><td colspan="2">4 ELEMENTS</td><td colspan="2">16 ELEMENTS</td><td colspan="2">64 ELEMENTS</td></tr>
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Figure 6b. A comparative graph and tabular recording of deflection at center of slab, from verification study using programs GTSTRUDL and E^3SAP for simply supported slab

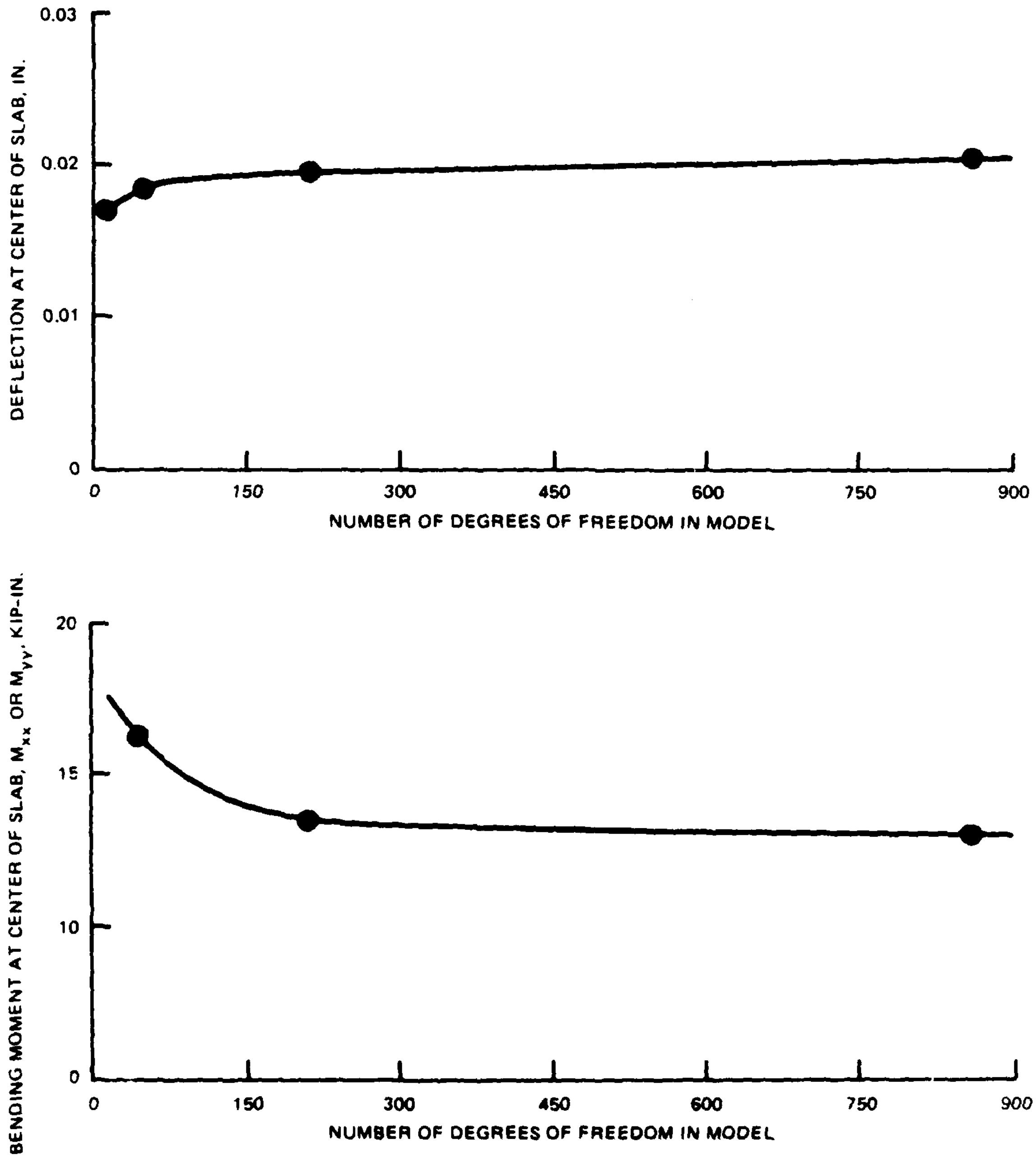


Figure 7. Graph of moment and deflection at center of slab from verification study using GTSTRUDL for fixed edge slab

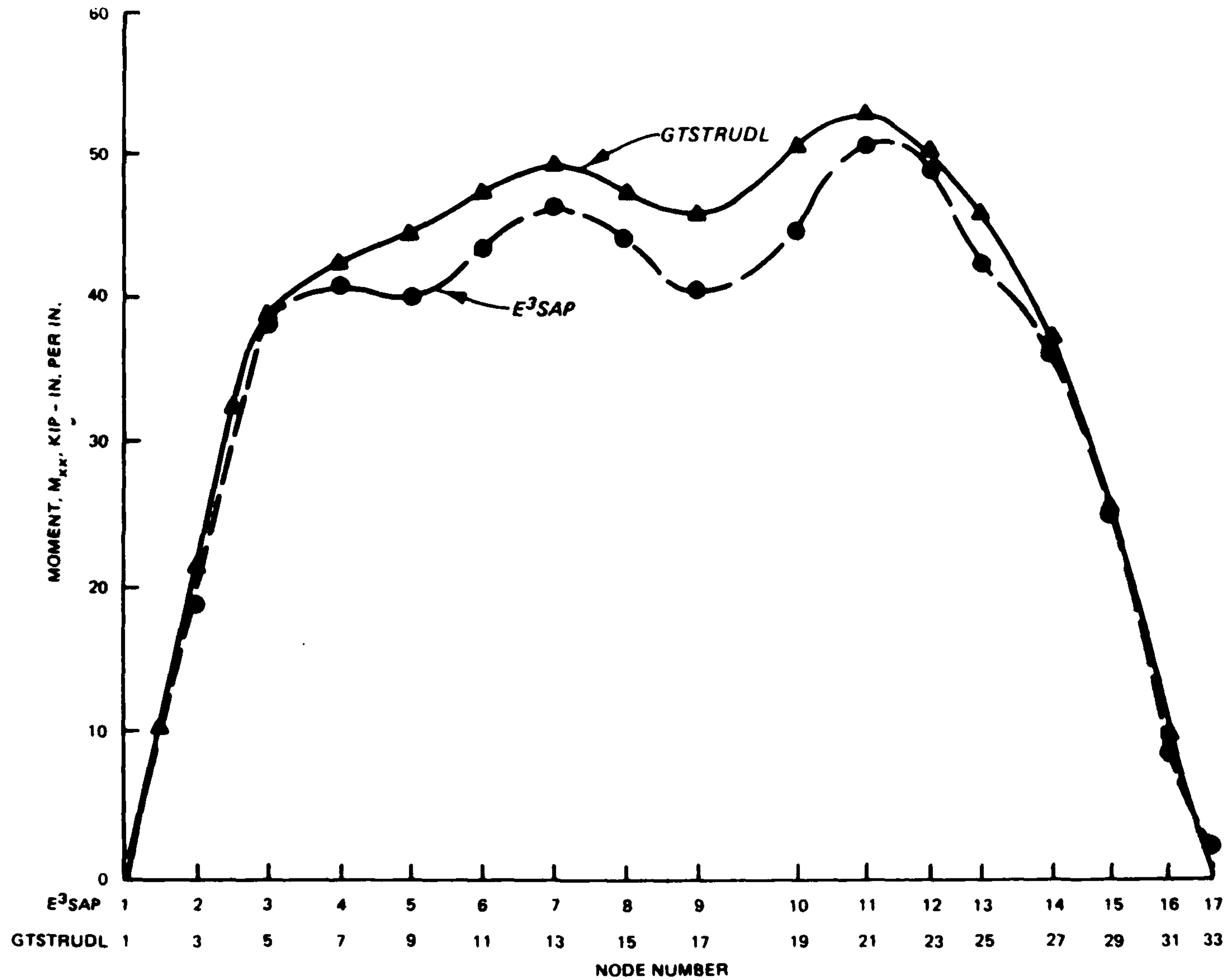


Figure 8. Moment, M_{xx}, along line 1 for comparing the results from GTSTRUDL and E^3SAP for the powerhouse slab

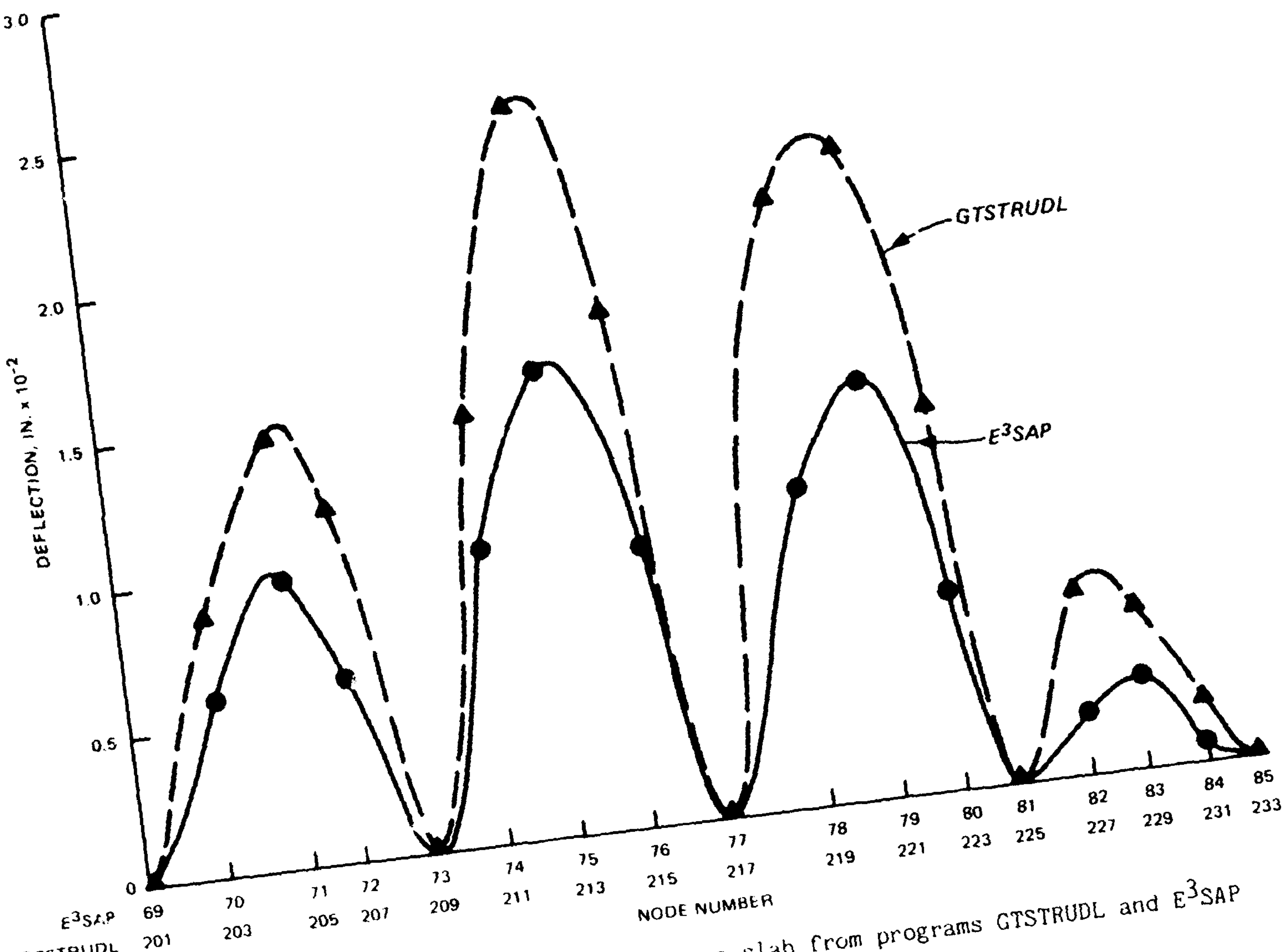


Figure 9. Deflections along line 2 in powerhouse slab from programs GTSTRUDL and E^{3}SAP

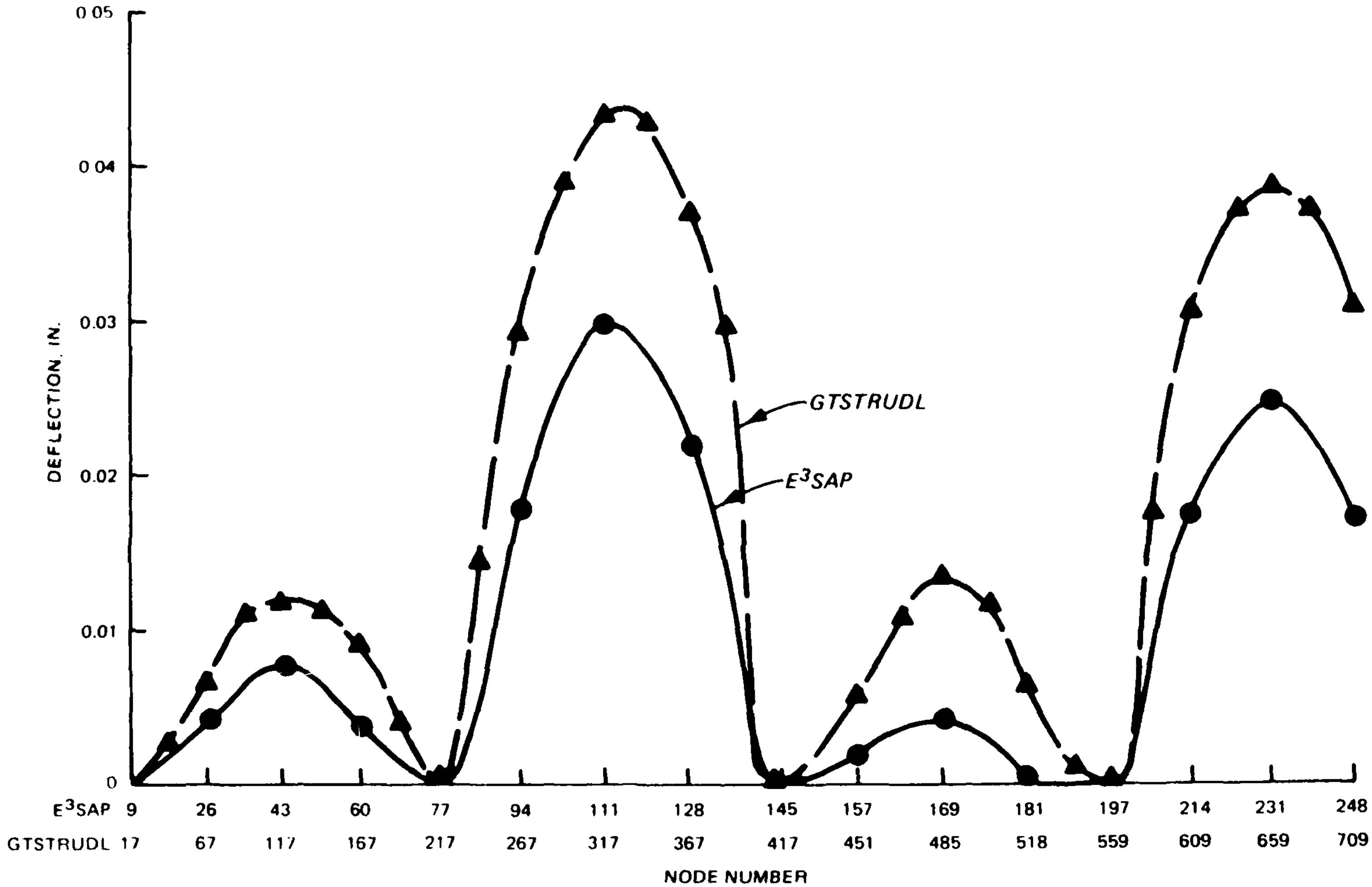


Figure 10. Deflections along line 3 in powerhouse slab from programs GTSTRUDL and E^3SAP

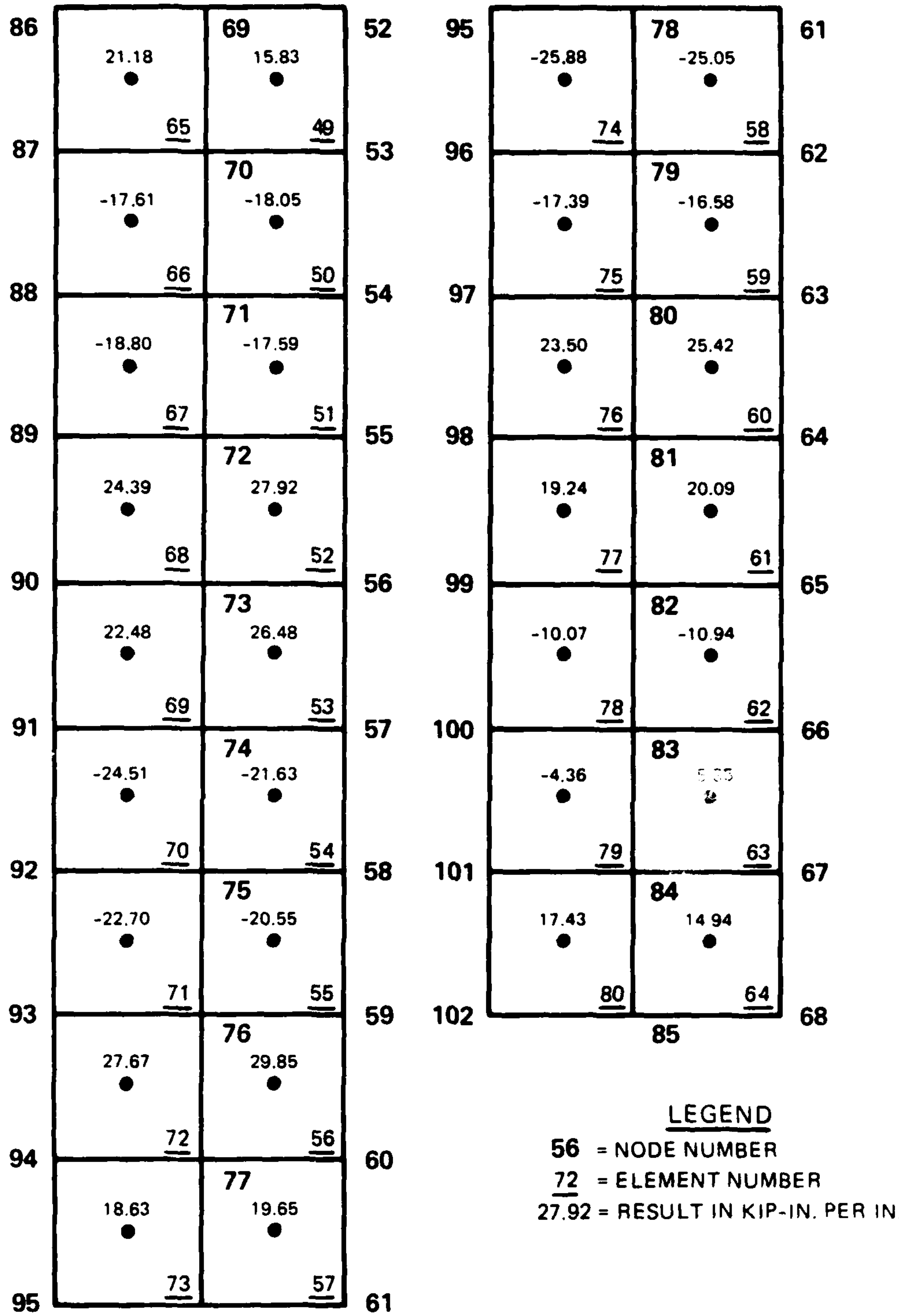


Figure 11a. Tabulation of E^3SAP moment, M_{yy}, results along line 2 in powerhouse slab (results at element centers)

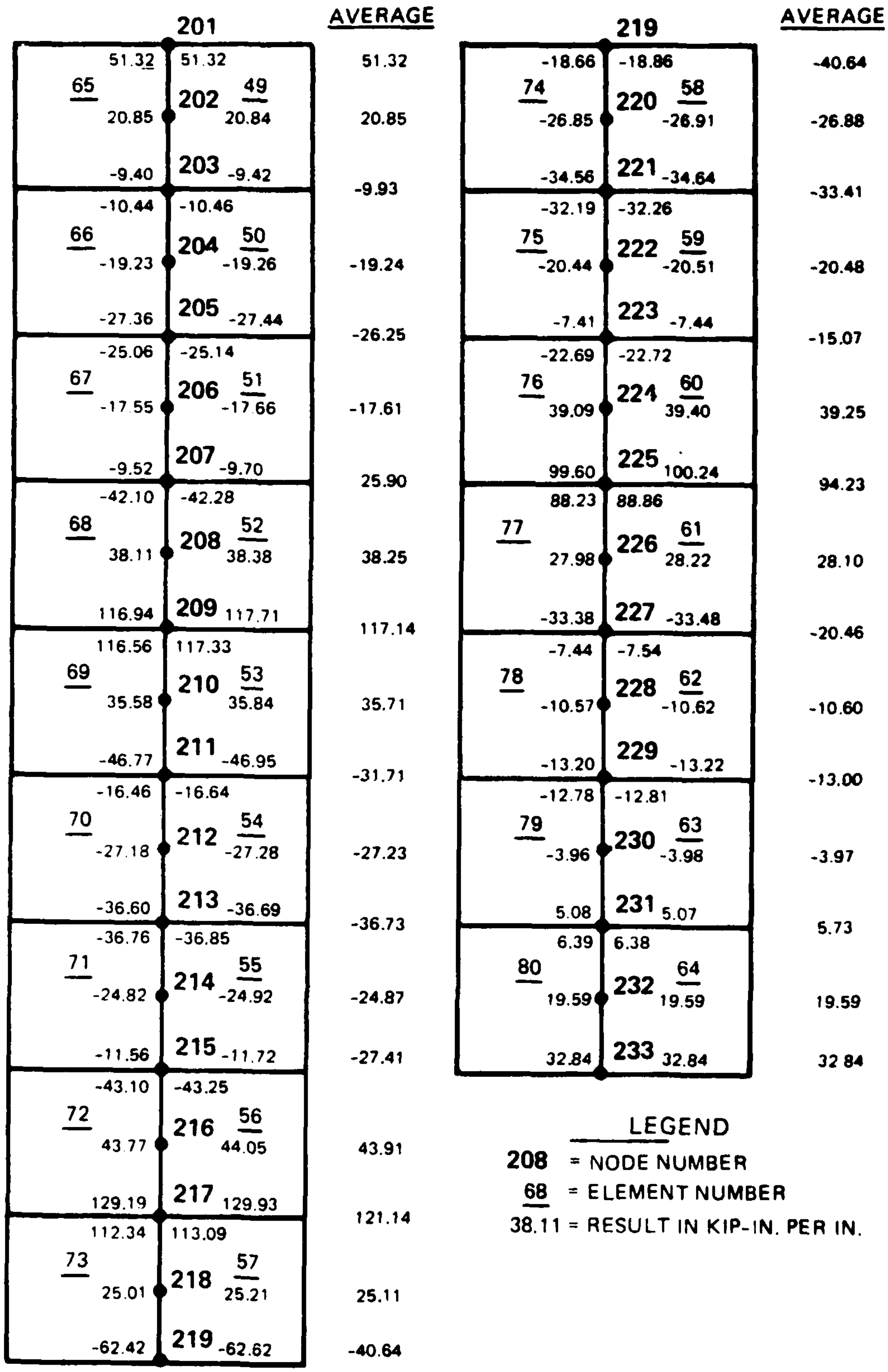


Figure 11b. Tabulation of GTSTRUDL moment, M_{yy}, results along line 2, (results at nodes)

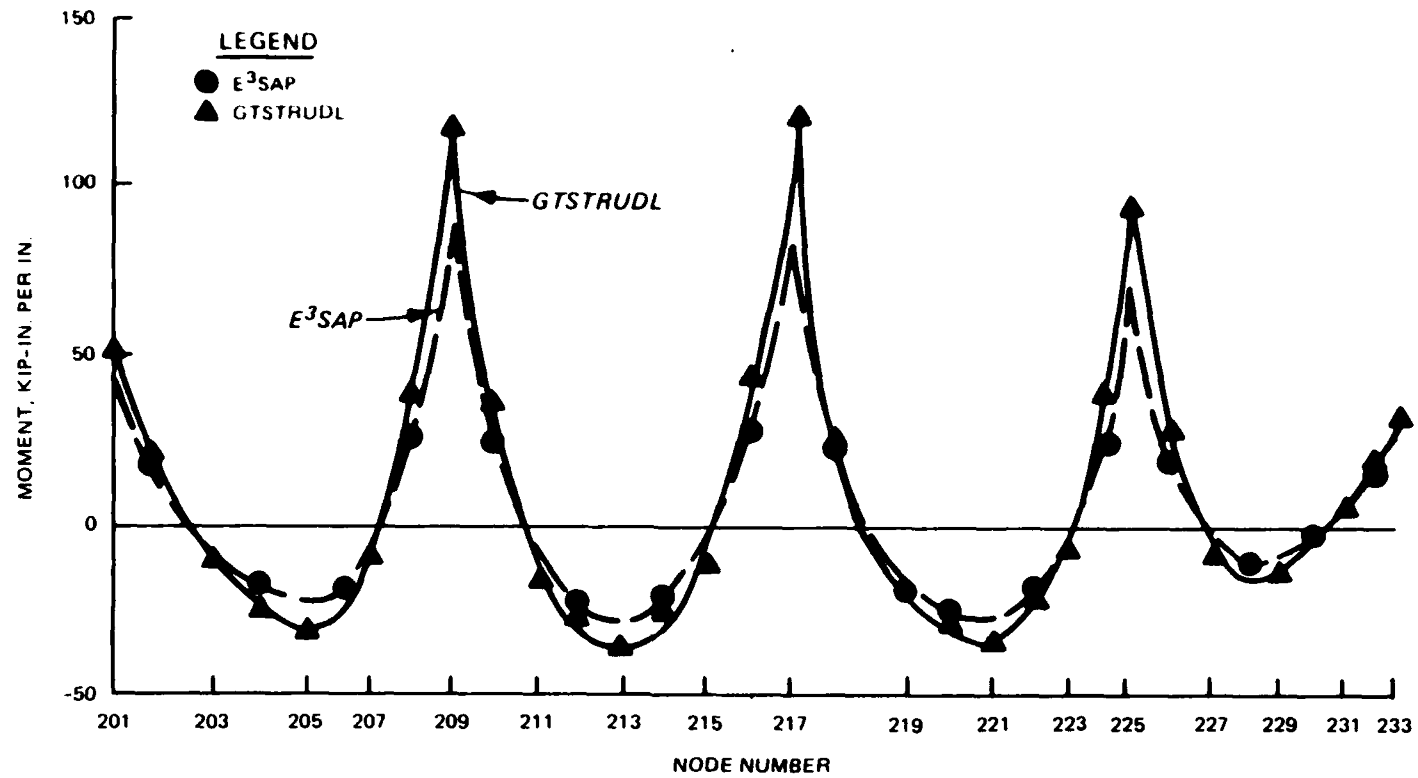


Figure 11c. Result comparison of moment, M_{yy}, along line 2 for programs GTSTRUDL and E^3SAP

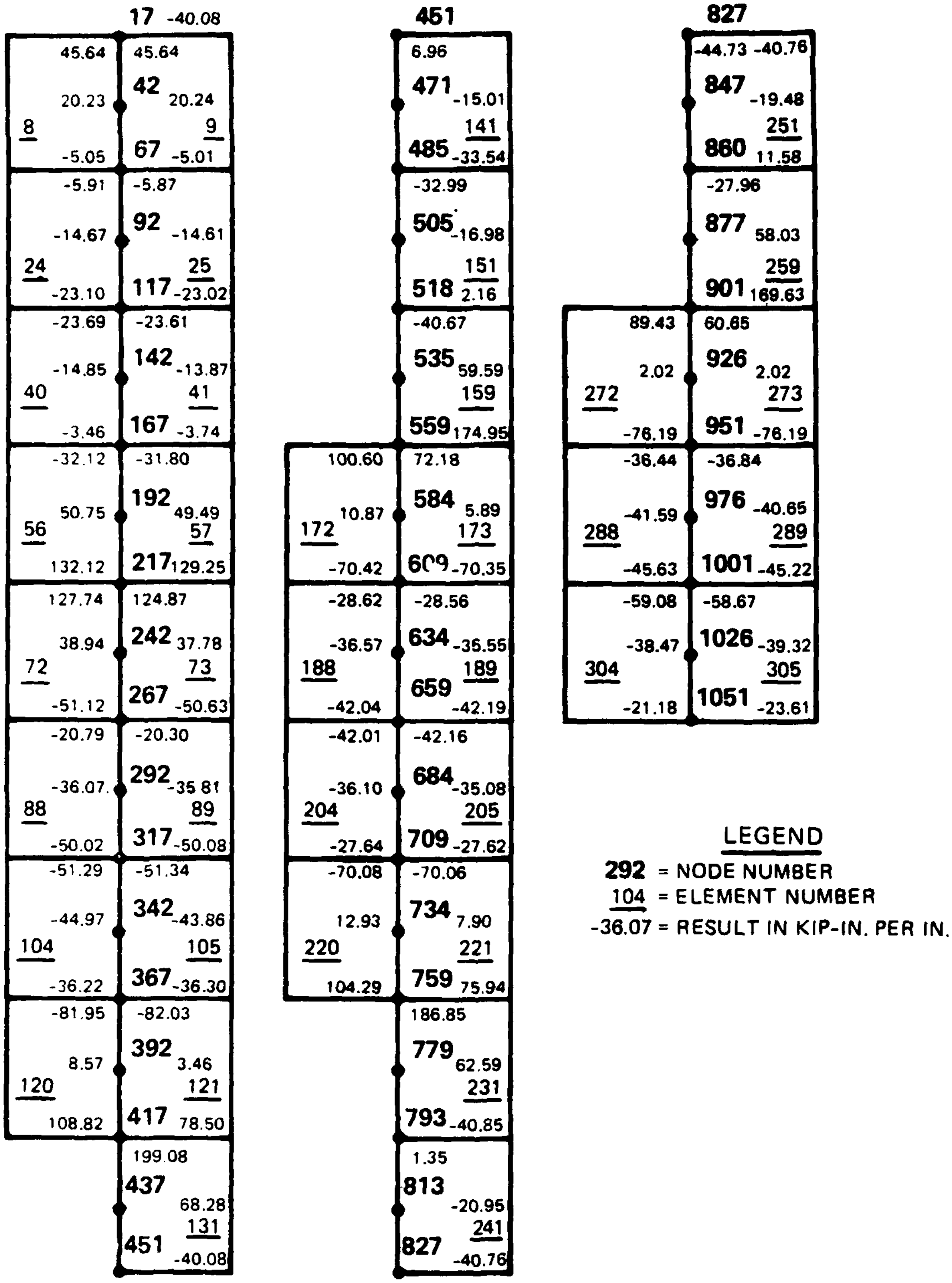


Figure 12a. Tabulation of GTSTRUDL moment, M_{xx}, results along line 3 (results at nodes)

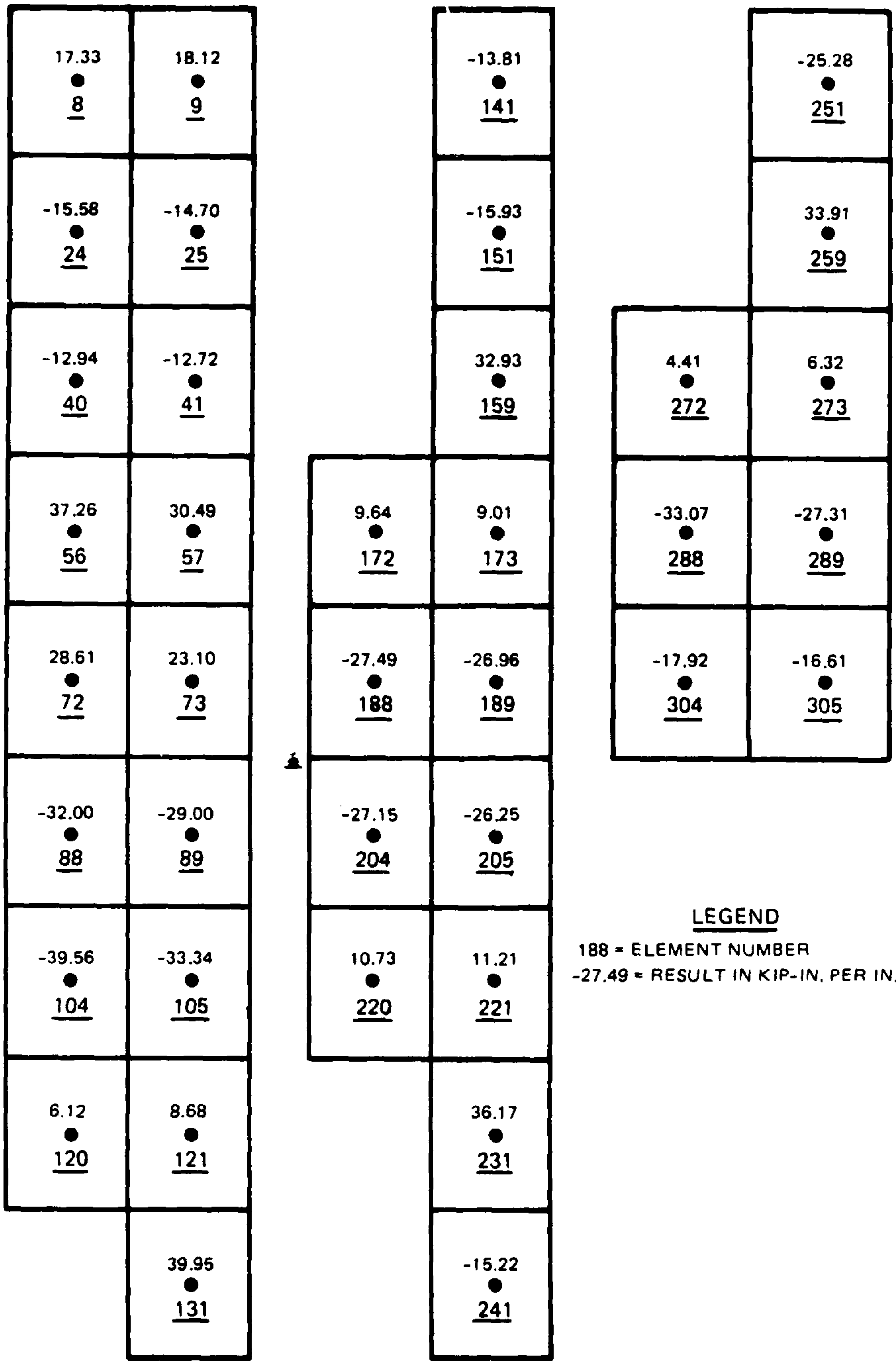


Figure 12b. Tabulation of E^3SAP moment, M_{xx}, results along line 3 (results at element center)

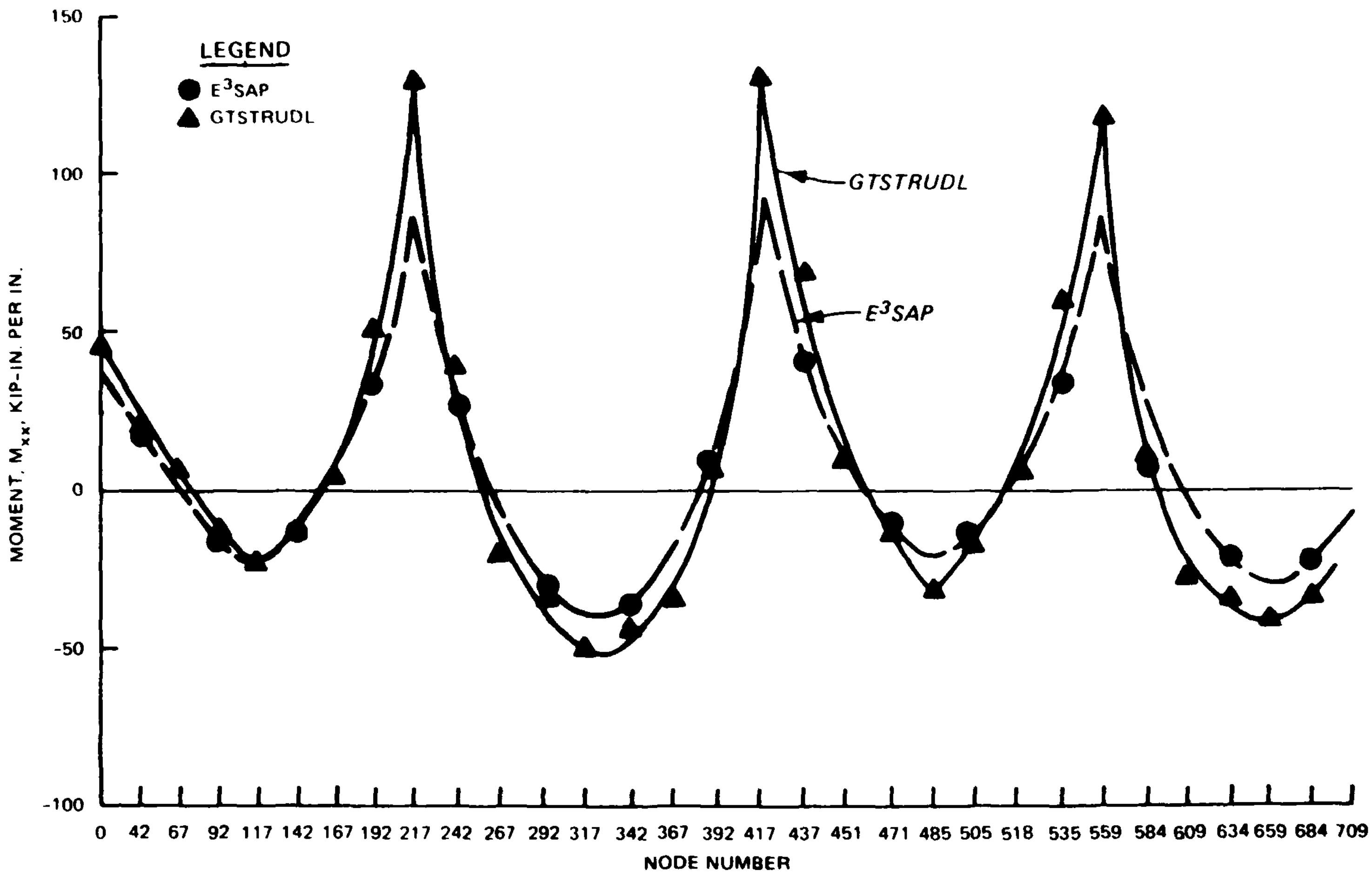
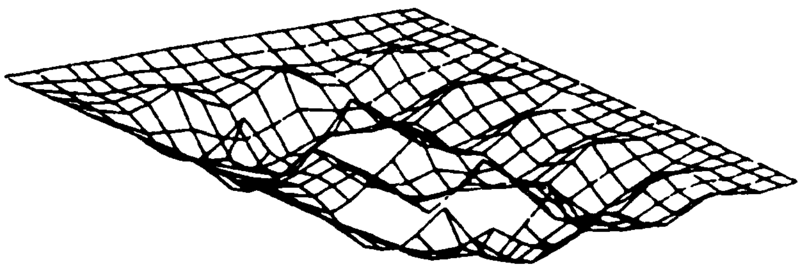


Figure 12c. Result comparison of moment, M_{xx}, along line 3 for programs GTSTRUDL and E^3SAP



LOAD CASE 1

Figure 13. Deflected shape plot of powerhouse slab from E^3SAP, fixed support condition

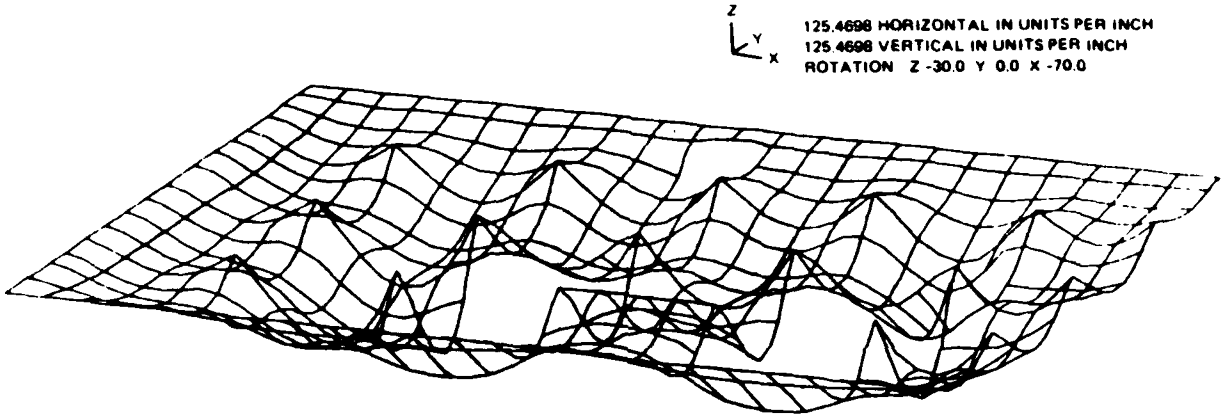


Figure 14a. Deflected shape of powerhouse slab from GTSTRUDL, fixed support condition

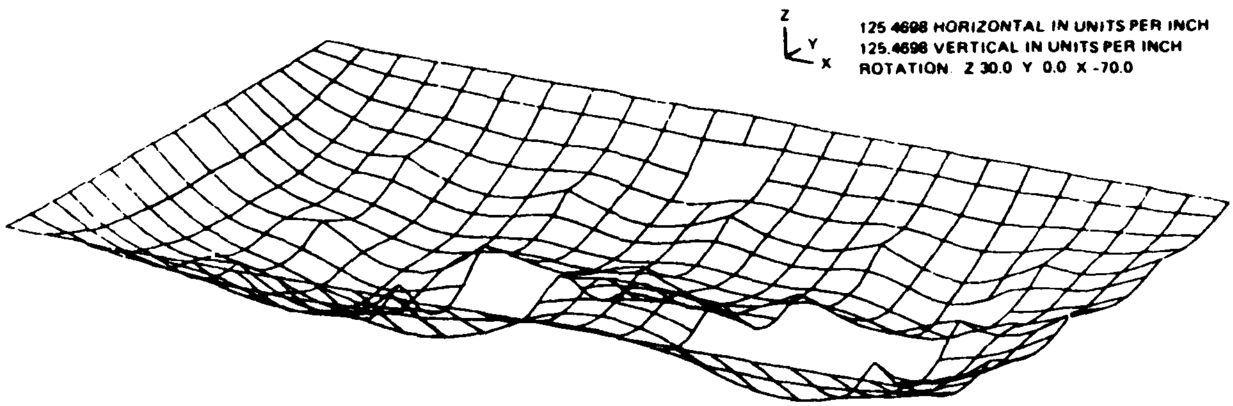


Figure 14b. Deflected shape of powerhouse slab from GTSTRUDL, elastic support condition

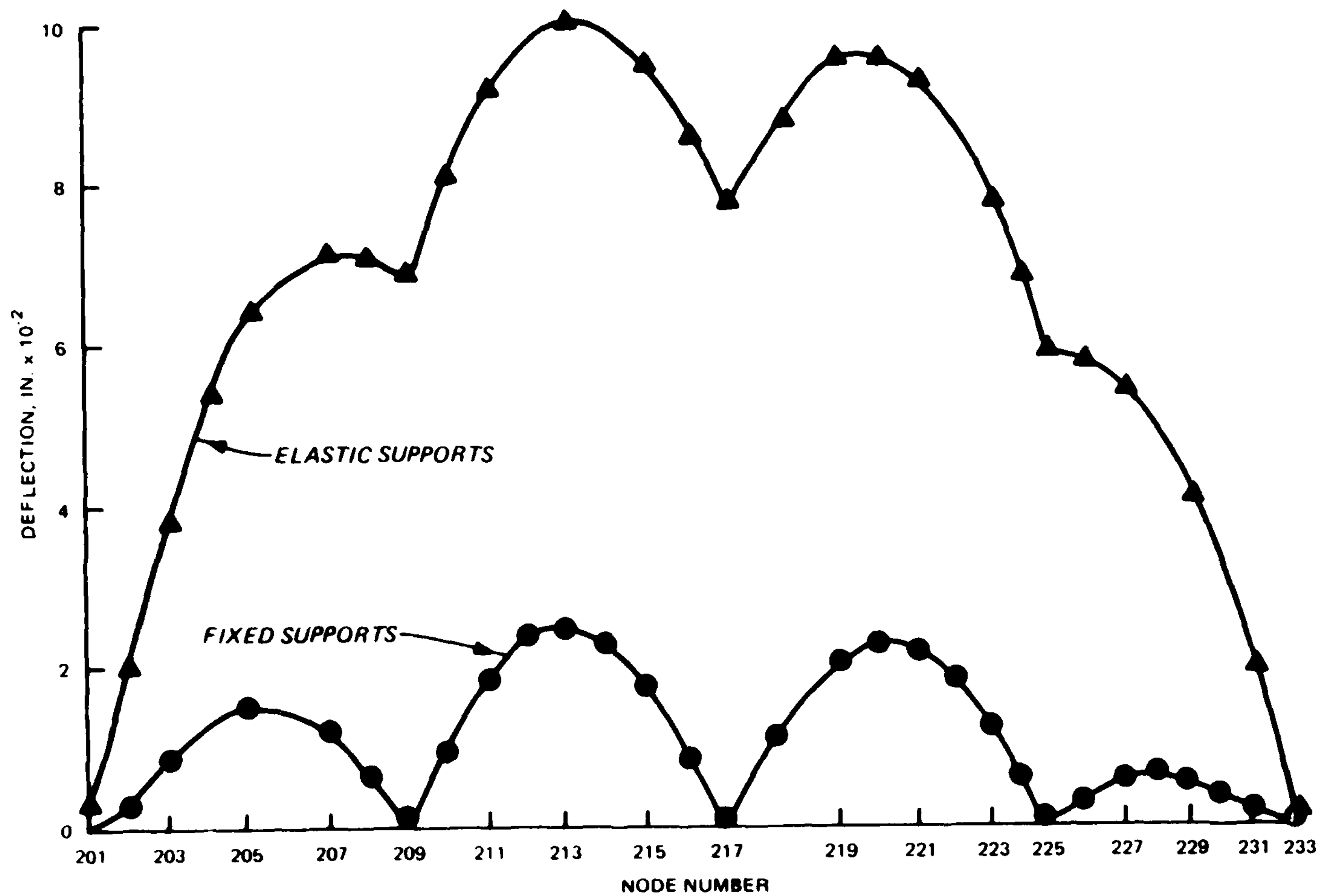


Figure 14c. Deflection comparison of powerhouse slab along line 2 from GTSTRUDL, fixed support versus elastic spring condition

NODE NUMBER	M_{xx} "FIXED" ANALYSIS KIP-IN. PER IN.	M_{xx} "SPRING" ANALYSIS KIP-IN. PER IN.
1	0.00	0.00
3	21.63	6.53
5	39.00	11.05
7	42.38	14.37
9	44.24	17.42
11	47.28	19.21
13	49.10	20.16
15	47.14	20.40
17	45.65	20.84
19	50.47	20.69
21	52.69	18.17
23	49.99	16.46
25	45.79	14.71
27	37.17	11.24
29	25.68	7.51
31	9.94	3.24
33	0.00	0.00

Figure 15a. Tabular record of moment, M_{xx}, along line 1 of powerhouse slab from GTSTRUDL comparing fixed-edge analysis versus elastic spring supports

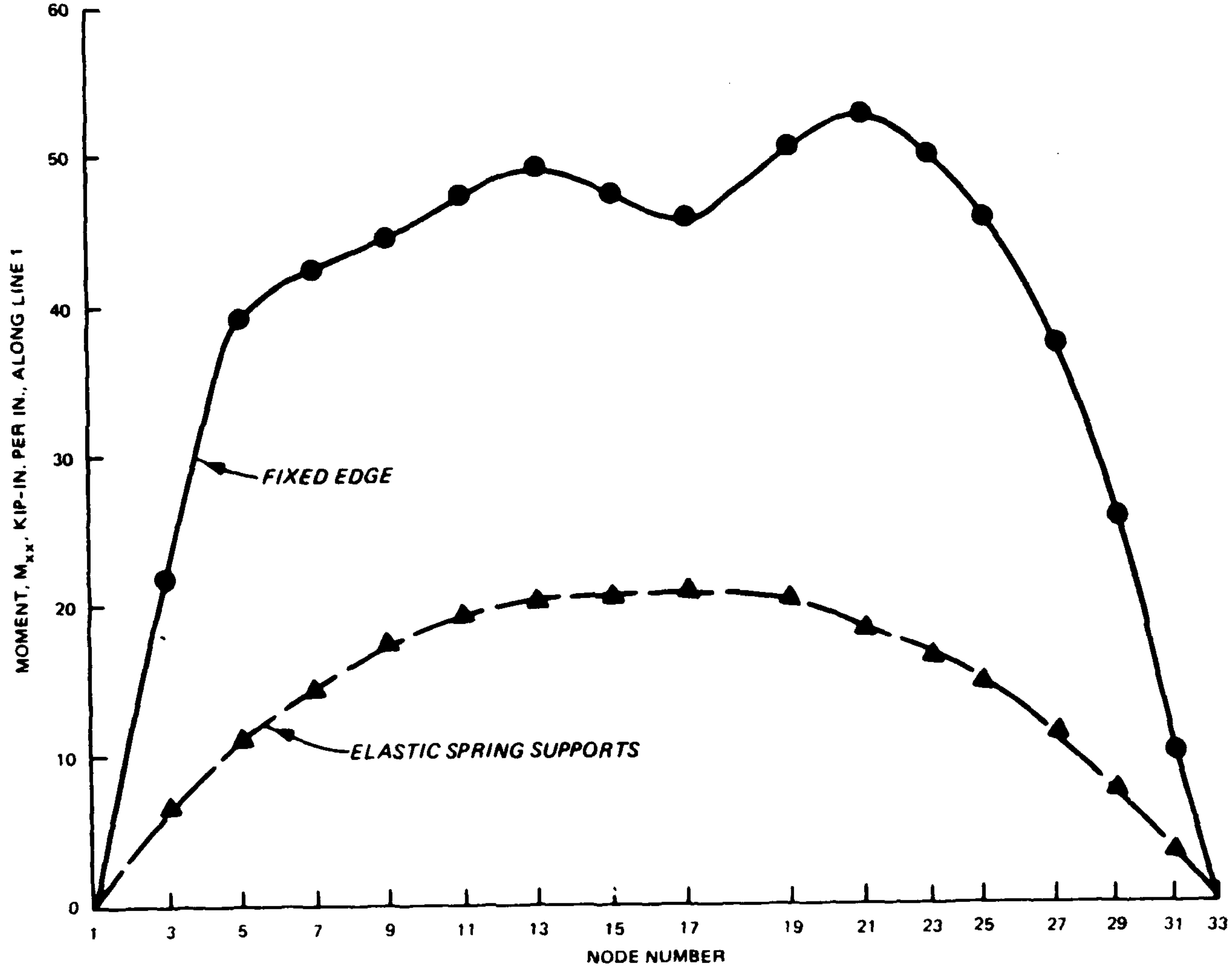


Figure 15b. Graphed record of moment, M_{xx} , along line 1 of powerhouse slab from GTSTRUDL comparing fixed-edge versus elastic spring support condition

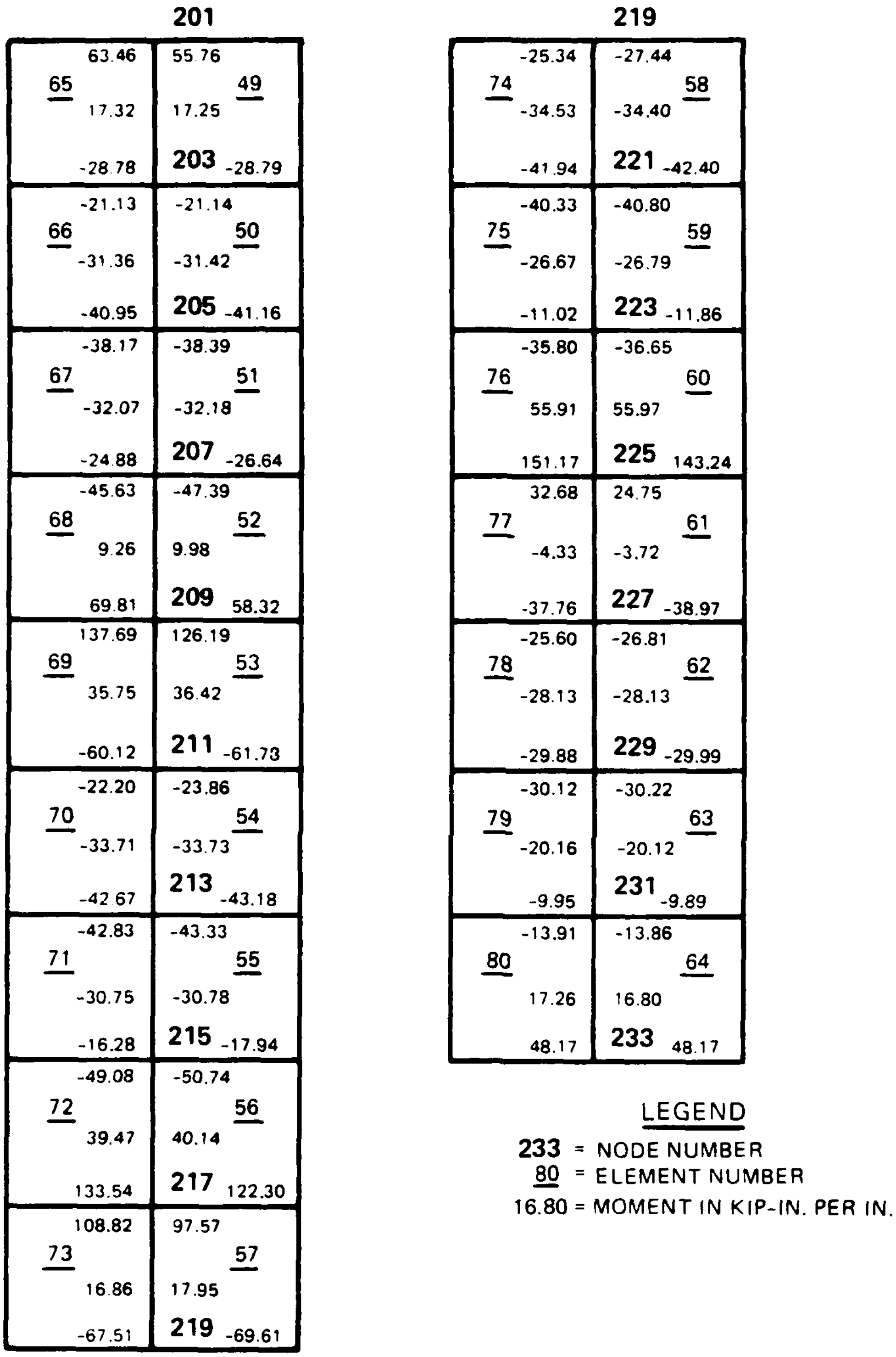


Figure 16a. Tabular record of moment, M_{yy}, along line 2 of powerhouse slab from GTSTRUDL with elastic supports (results at nodes)

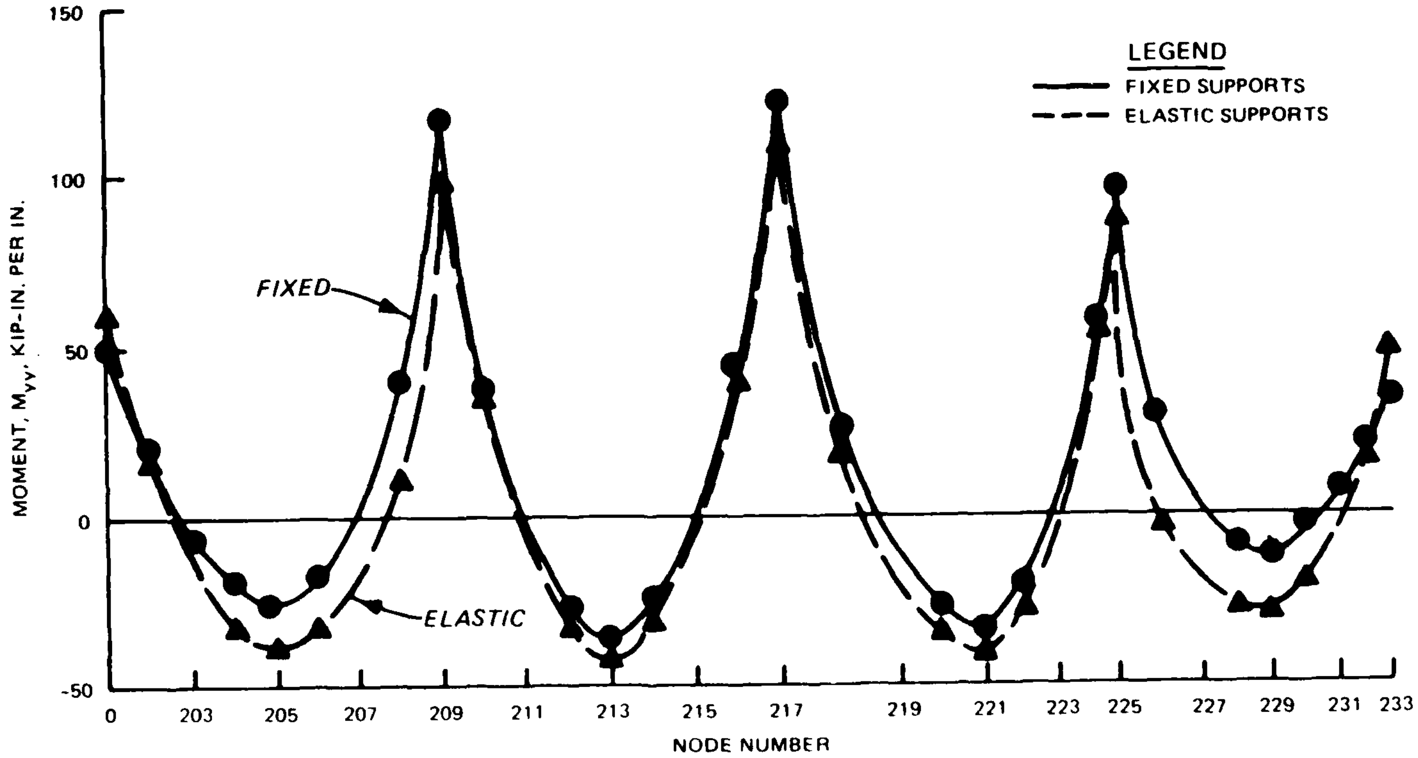


Figure 16b. Graphed record of moment, M_{yy}, along line 2 of powerhouse slab from GTSTRUDL comparing fixed support versus elastic support condition

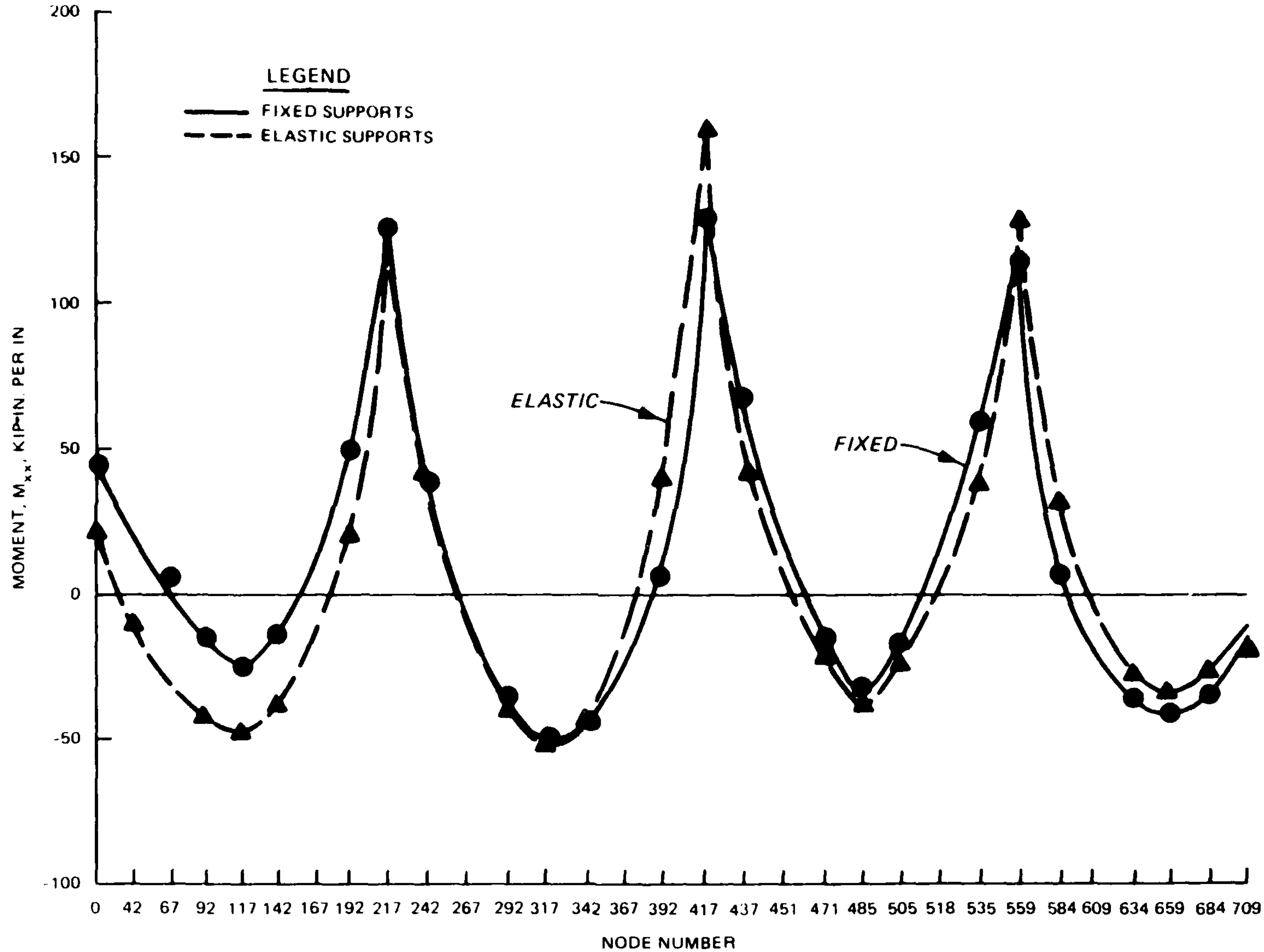


Figure 17. Graphed record of moment, M_{xx}, along line 3 of powerhouse slab from GTSTRUDL comparing fixed support versus elastic support condition

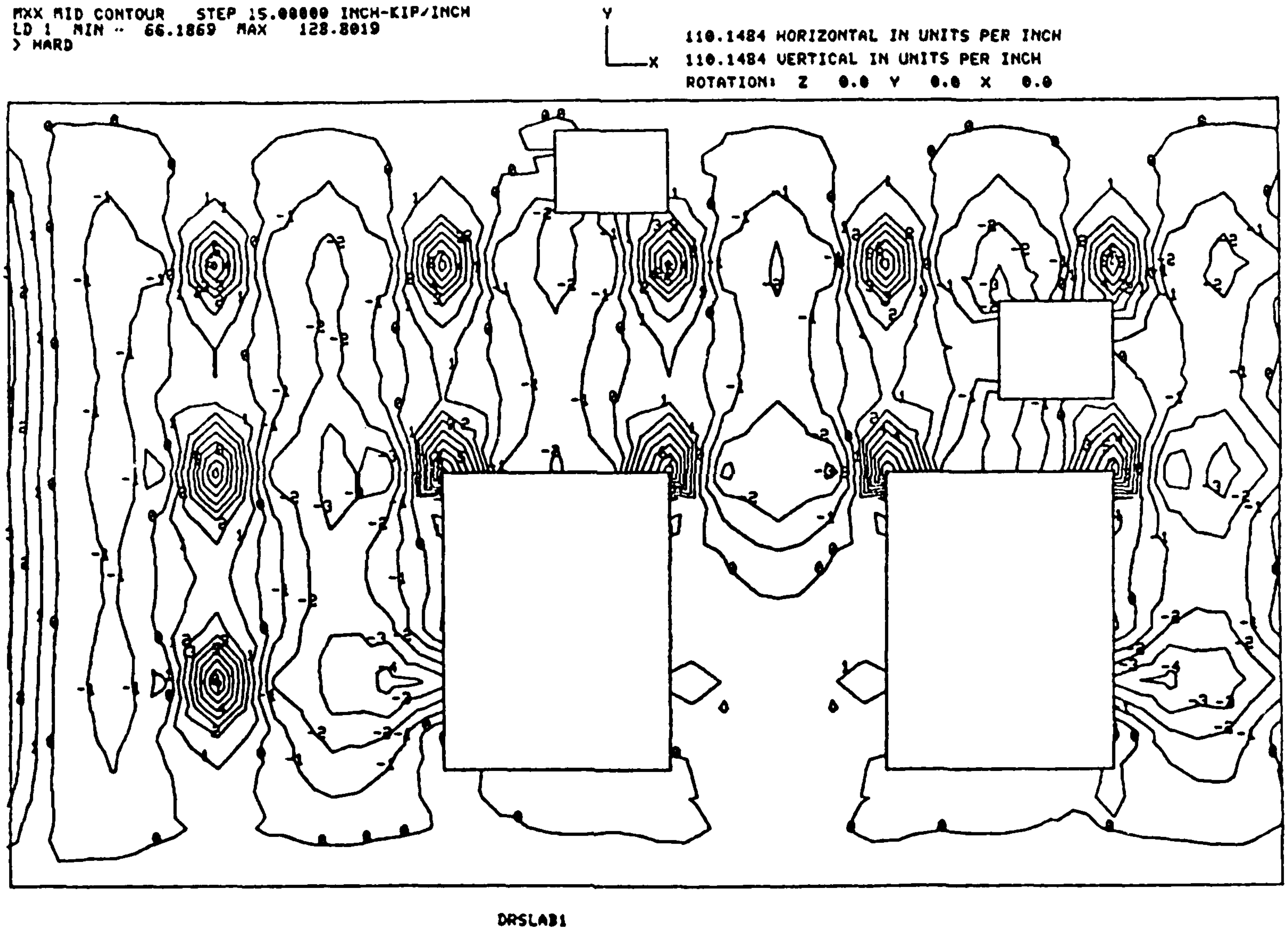


Figure 18. Moment contour plot, M_{xx}, for GTSTRUDL analysis of slab with fixed supports

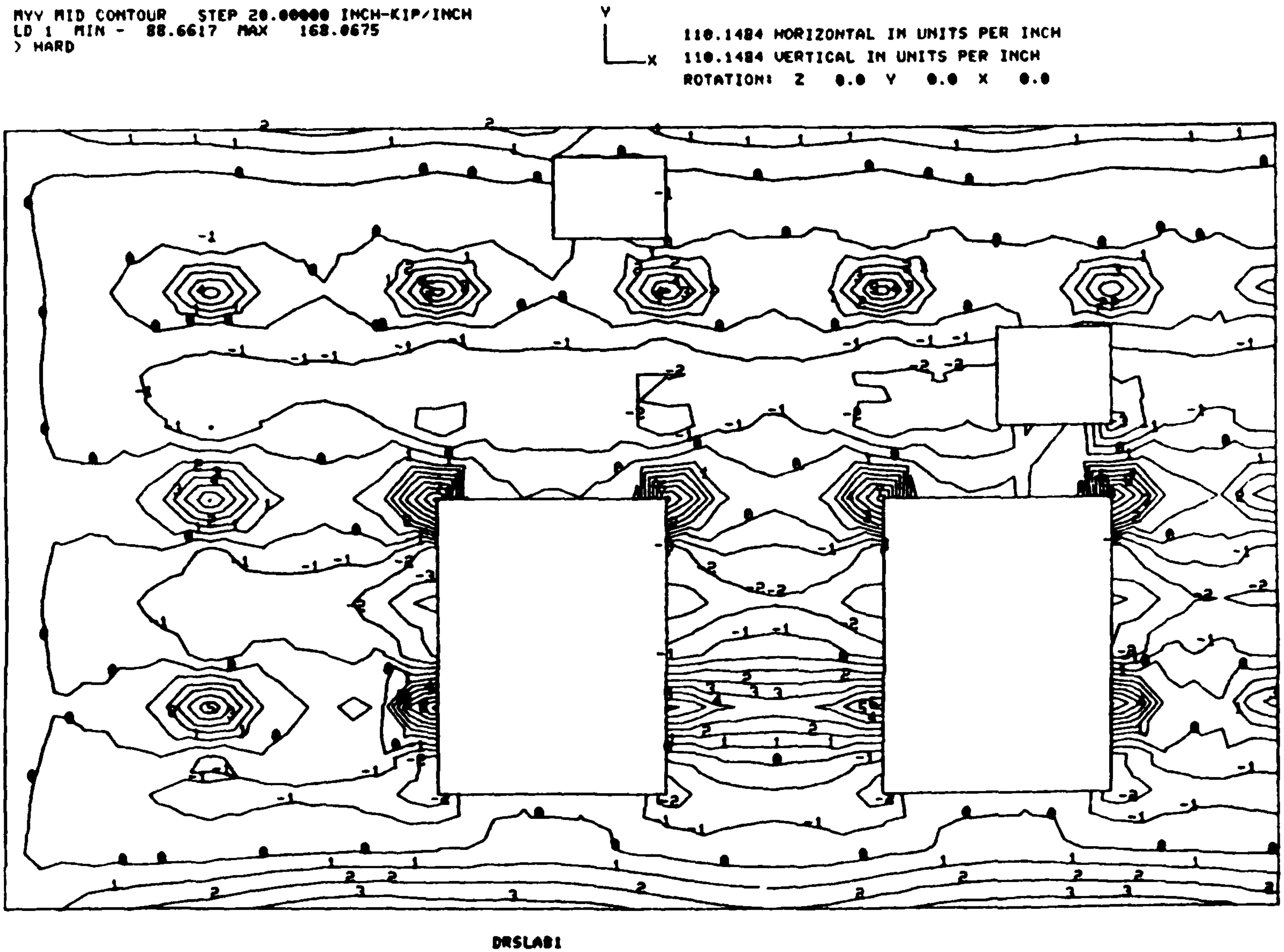


Figure 19. Moment contour plot, M_{yy} , for GTSTRUDL analysis of slab with fixed supports

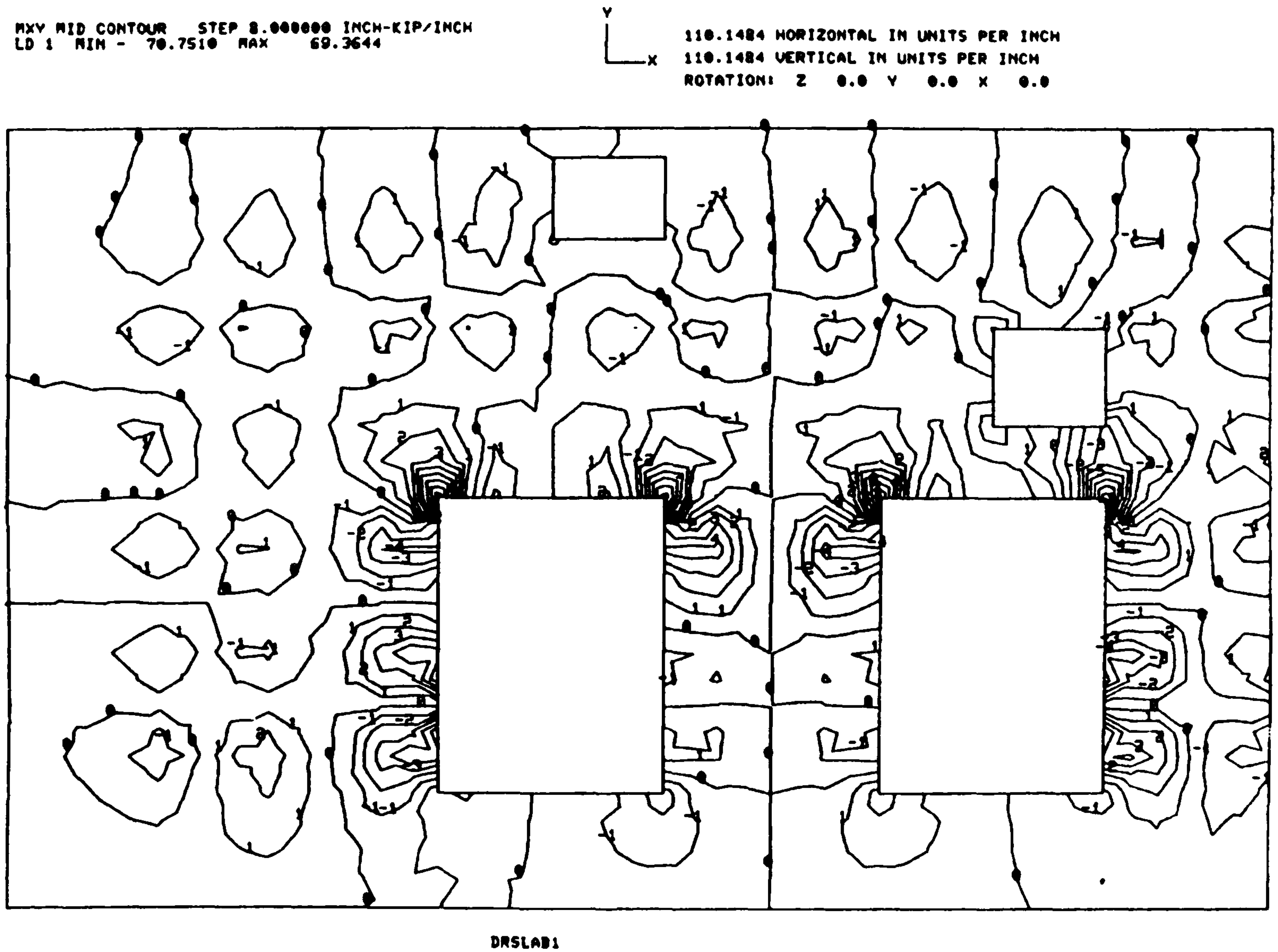


Figure 20. Moment contour plot, M_{xy}, for GTSTRUDL analysis of slab with fixed supports

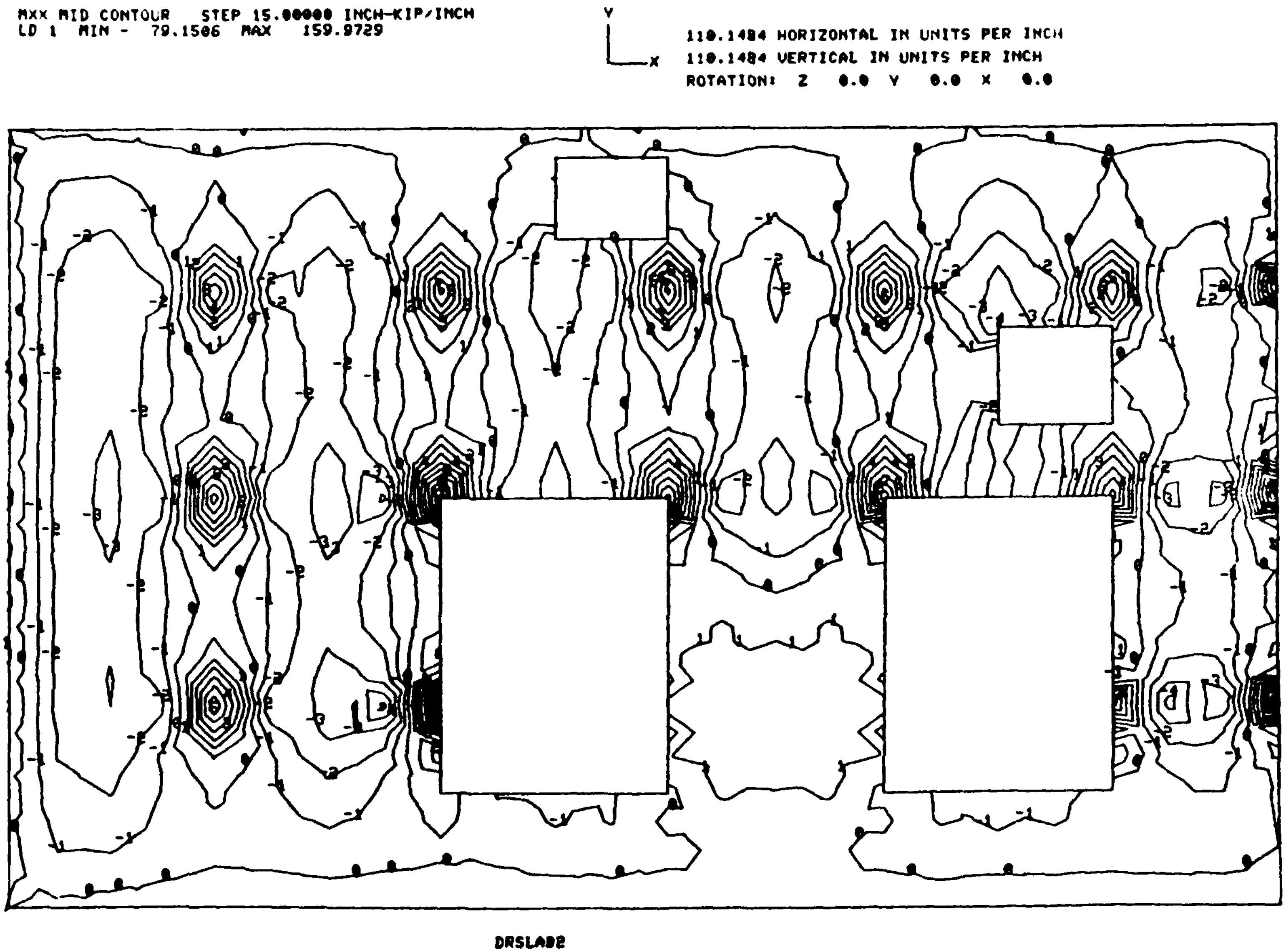


Figure 21. Moment contour plot, M_{xx} , for GTSTRUDL analysis of slab with elastic supports

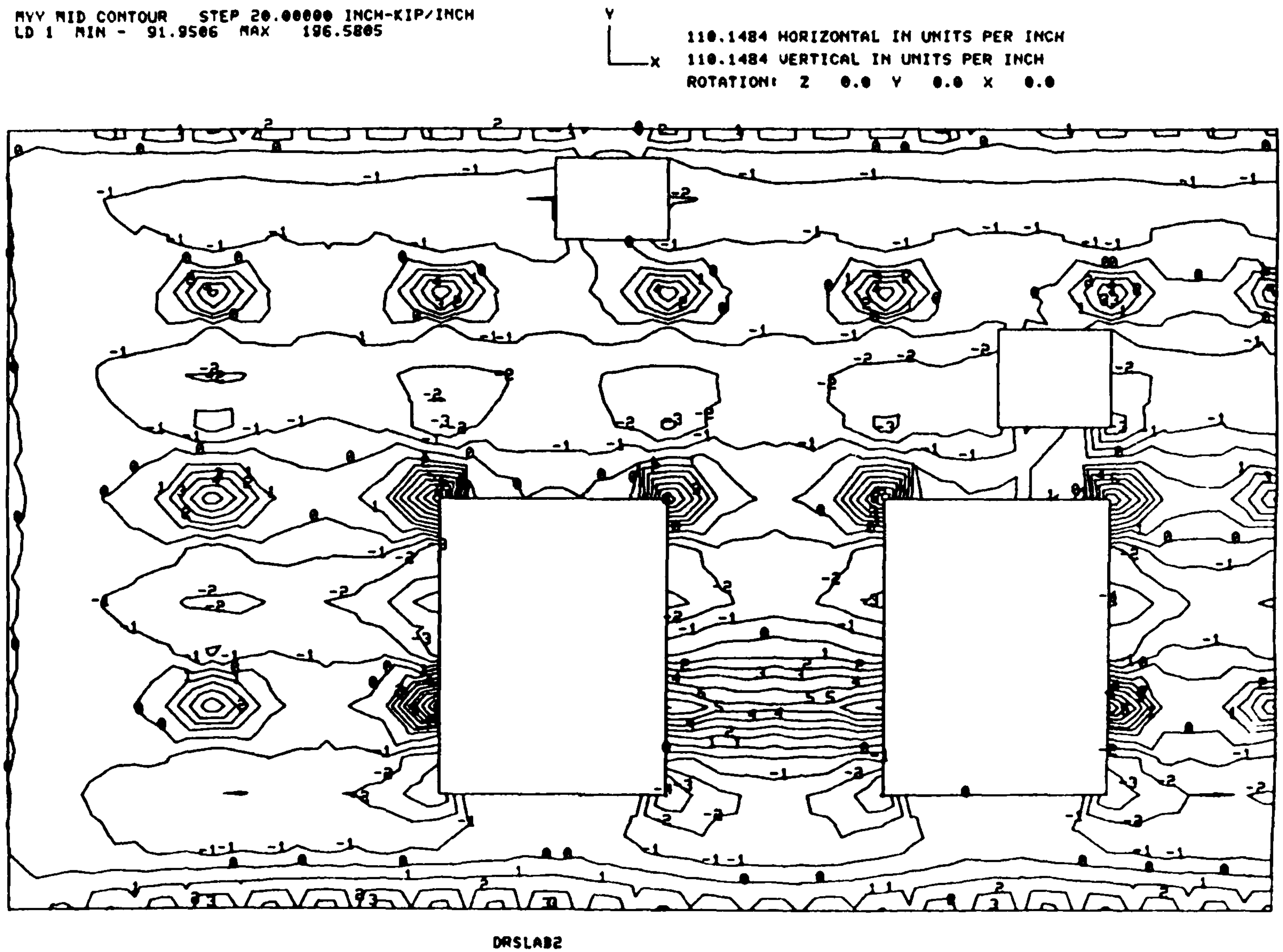


Figure 22. Moment contour plot, M_{yy}, for GTSTRUDL analysis of slab with elastic supports

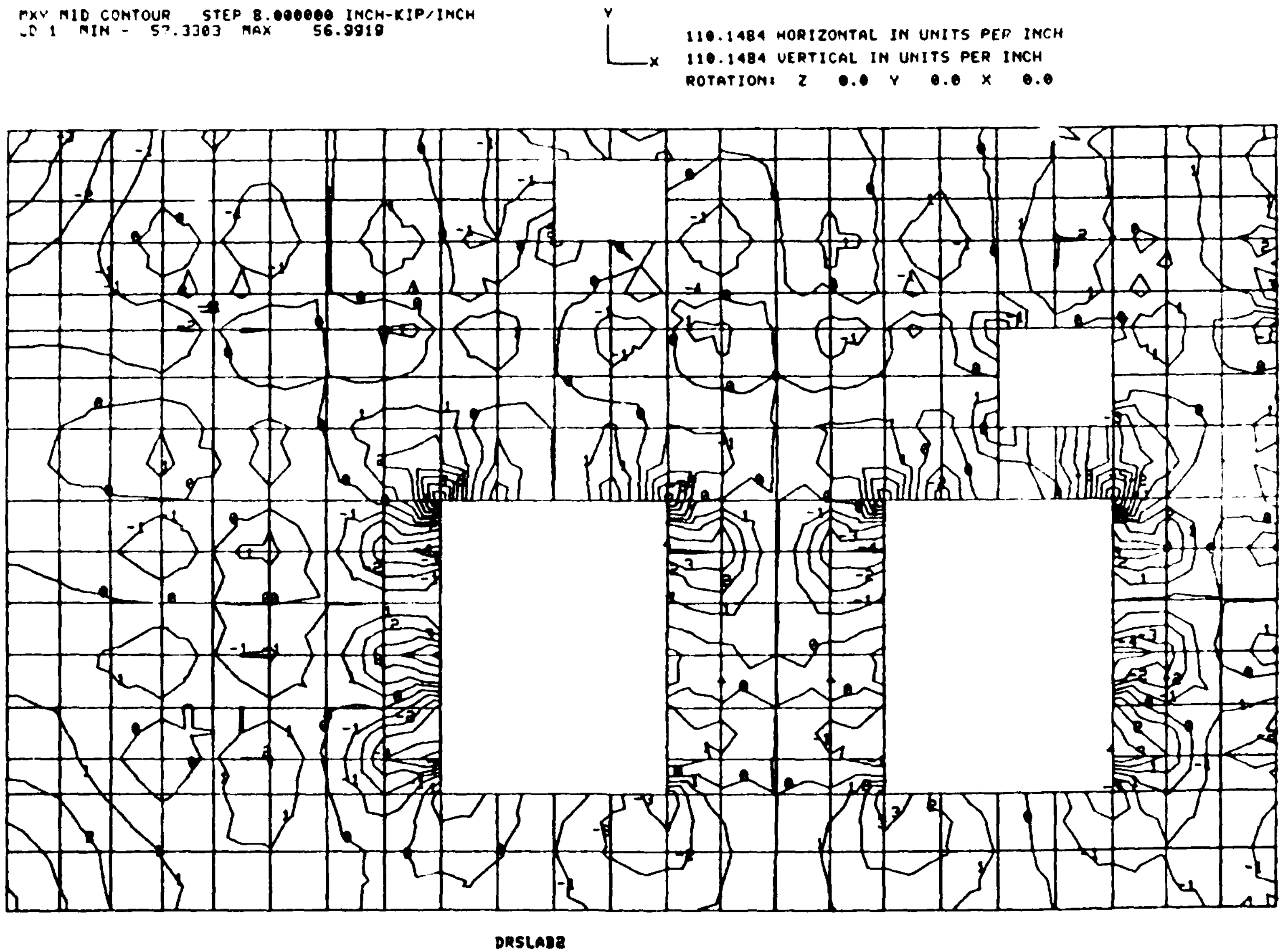


Figure 23. Moment contour plot, M_{xy}, for GTSTRUDL analysis of slab with elastic supports

PART V: INTERPRETATION OF RESULTS

Comparison Indications

15. This study indicated that the selected GTSTRUDL element will produce results approaching the theoretical values for the simply supported slab. Convergence to these values occurs on an asymptotic curve and practical results can be obtained by using a relatively coarse mesh. The comparison between the E^3SAP membrane element and the GTSTRUDL IPBQQ element indicates that as the span/thickness ratio decreases, the contribution of shear to the deformation becomes more important. The practical guide in past years has been to neglect shear deformation if the span/thickness ratio is 10 or larger. In this study, for a span/thickness ratio equal to 10, the shear deformation resulted in only a 2 percent difference in deflection.

Slab Analysis

16. The powerhouse slab has a maximum span/thickness ratio of 7.3 and a minimum ratio of 5.1. Comparisons of the E^3SAP and GTSTRUDL models (refer to Figures 9 and 10) show that the deflections increased by as much as 56 percent when shear deformations were included with the IPBQQ element. Moments increased by a maximum of 30 percent in some areas, although the moment curves are usually quite close (Figures 11c and 12c). Compared to the results of the verification study, it can be seen that decreasing the span/thickness ratio smaller than 10 caused large changes in the shear deformation.

17. Upon closer study of the finite element solution for the slab, particularly the GTSTRUDL analysis, it became apparent that the mesh used for this analysis gave good overall results. However, in areas where the moment is rapidly changing, the stress analysis falls short of the desired solution. Figure 11b. M_{yy} along line 2, and Figure 12a, M_{xx} moments along line 3, show the disparity in computed moments at a common node in areas where the moment is rapidly changing. The reader must realize that a finer mesh is desirable in areas such as around the pinned supports used to model the supporting columns, and in areas where the geometry changes abruptly, such as the corners of the openings in the slab.

Slab Analysis with Elastic Spring Supports

18. The deflection comparison along line 2, Figure 14c, dramatically illustrates the large change in deflections in the slab analysis when the fixed supports are replaced by elastic spring supports. It is evident that the "pin" assumption for the column in the previous analysis was not particularly valid. The moment comparison along line 1, Figures 15a and 15b, shows the large change that took place for the negative moments along the end wall. The maximum moment decreased by 61 percent due to rotation of the end wall. Interestingly, the moment along line 2 changed very little from the previous analysis, as indicated in Figures 16a and 16b. Also, inspection of M_{xx} along line 3, Figure 17, shows that it has not changed from the fixed support condition except at the connection to the end wall where, again, elastic rotation of the wall caused a reduction in negative moments.

19. The major difference between the two analyses is the deflections at the columns and rotation of the end wall in the elastic support analysis.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

20. The finite element program GTSTRUDL can be used to advantage in the analysis of concrete slabs with configurations that rule out conventional analysis methods. The IPBQQ element in the GTSTRUDL library is particularly useful if the slab has a span/thickness ratio of less than 10. This study bears out the assumption that the contribution of shear to deflections become a major contributor to the deflection of this type of slab when the ratio is less than 10.

Recommendations

21. The engineer should make some verification studies for his particular problem so the proper mesh size can be selected to give usable results. The IPBQQ element allows stress and moment contour plotting as shown in Figures 18 through 23. This graphical interpretation of the output makes the job of the engineer more pleasant. The analyses pointed out the necessity for finer meshes in high stress areas. Should the engineer be interested in moments and shears near discontinuities, such as corners of openings or concentrated loadings, a finer mesh size at these points must be used.

22. The elastic spring supports analysis suggested that engineers look closely at fixity assumptions when modeling concrete slabs. Wall rotations and column shortening will give dramatically different deflection values, and negative moments will lessen considerably in some instances, as the example for this study shows.

23. When the slab has a span/thickness ratio of 10 or less, the design engineer should evaluate the need for using an element that models the shear contribution to deflections.

APPENDIX A: GTSTRUDL INPUT FILES

1. A verification study of the GTSTRUDL model involved analyses of the problem with two different boundary conditions. Input files for slabs with fixed supports and slabs with elastic spring supports are shown in this appendix.

Slabs with Fixed Supports

2. The GTSTRUDL input file for slabs with fixed supports is printed on this and the following pages.

```
STRUDL 'SLAB' 'BONNEVILLE ERECTION BAY SLAB'
UNITS FEET KIPS
TYPE PLATE BENDING
GENER 33 JOINT ID 1 1 X 0. 0. Y LIST 0. 2.875 5.75 8.625 11.5 13.25 -
 15. 17.5 20. 22.5 25. 27.5 30. 32.5 35. 37.5 40. 43.5 47. 49.5 52. -
 54.25 56.5 58.25 60. 62.5 65. 67. 69. 71. 73. 74.5 76. SUP
MODIFY 4 ID 50 X 5. Y 0.
GENER 33 JOINT ID 251 1 X 25.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 -
13.25 15 17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 43.5 47 49.5 52 -
54.25 56.5 58.25 60 62.5 65 67 69 71 73 74.5 76. SUP
MODIFY 3 ID 50 X 5.5 Y 0.
GENER 17 JOINT ID 34 1 X 2.5 0. Y LIST 0. 5.75 11.5 15 20 25 30 35 -
 40 47 52 56.5 60 65 69 73 76 SUP
MODIFY 3 ID 50 X 5. Y 0.
GENER 17 JOINT ID 234 1 X 22.75 0. Y LIST 0. 5.75 11.5 15 20 25 30 -
35 40 47 52 56.5 60 65 69 73 76 SUP
MODIFY 3 ID 50 X 5.5 Y 0.
GENER 22 JOINTS ID 446 1 X 47.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 40. -
43.5 47 49.5 52. 54.25 56.5 58.25 60 62.5 65 67 69 71 73 74.5 76 SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 12 JOINTS ID 434 1 X 44.75 0 Y LIST 0 5.75 11.5 40 47 52 56.5 60 -
65 69 73 76. SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 19 JOINTS ID 513 1 X 58.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 40. -
43.5 47 49.5 52 54.25 56.5 58.25 60 62.5 65 73 74.5 76 SUP
GENER 11 JOINTS ID 502 1 X 55.75 0. Y LIST 0. 5.75 11.5 40 47 52 56.5 60 65 -
73  76 SUP
MODIFY 1 ID 30 X 5.5 Y 0.
GENER 33 JOINTS ID 543 1 X 64. 0 Y LIST 0. 2.875 5.75 8.625 11.5 13.25 15 -
17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 43.5 47 49.5 52 54.25 56.5 58.25 -
60 62.5 65 67 69 71 73 74.5 76 SUP
MODIFY 4 ID 50 X 5.25 Y 0.
GENER 17 JOINTS ID 576 1 X 66.625 0 Y LIST 0. 5.75 11.5 15 20 25 30 35 40 -
47 52 56.5 60 65 69 73 76 SUP
MODIFY 3 ID 50 X 5.25 Y 0.
GENER 22 JOINTS ID 788 1 X 90.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 40. 43.5 -
47 49.5 52. 54.25 56.5 58.25 60. 62.5 65 67 69 71 73 74.5 76 SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 12 JOINTS ID 776 1 X 87.75 0. Y LIST 0. 5.75 11.5 40 47 52 56.5 60 -
65 69 73 76 SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 19 JOINTS ID 855 1 X 101.5 0. Y LIST 0 2.875 5.75 8.625 11.5 40 43.5 -
47  56.5 58.25 60 62.5 65 67 69 71 73 74.5 76 SUP
GENER 11 JOIN ID 844 1 X 98.75 0. Y LIST 0 5.75 11.5 40 47 56.5 60 65 69 73 -
76 SUP
MODIFY 1 ID 30 X 5.5 Y 0.
GENER 33 JOINTS ID 885 1 X 107. 0. Y LIST 0. 2.875 5.75 8.625 11.5 13.25 15 -
17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 43.5 47 49.5 52 54.25 56.5 58.25 60 -
```

GTSTRUDL input file for slabs with fixed supports--continued

```
6[illegible].5 65 67 69 71 73 74.5 76 SUP
MODIFY 3 ID 50 X 5.333 Y 0.
GENERATE 17 JOINTS ID 918 1 X 109.666 0. Y LIST 0. 5.75 11.5 15 20 25 30 35 40 -
4[illegible] 52 56.5 60 65 69 73 76 SUP.
MODIFY 2 ID 50 X 5.333 Y 0.
STATUS [illegible] 35 TO 49 52 TO 82  85 TO 99 102 TO 132 135 TO 149 152 TO 182 -
1[illegible] TO [illegible] 202 TO 208 210 TO 216 218 TO 224 226 TO 232 235 TO 249 252 TO 282 -
285 TO 299 302 TO 332 335 TO 349 352 TO 382 385 TO 399 402 TO 408 410 TO 416 -
  426 TO 432 435 TO 444 447 TO 466 469 TO 478 481 TO 500 503 TO 511 -
514 TO 530 533 TO 541 544 TO 550 552 TO 558 560 TO 566 568 TO 574 577 TO 579 -
581 TO 591 594 TO 600 602 TO 624 627 TO 629 631 TO 641 644 TO 650 652 TO 674 -
677 TO 679 681 TO 691 694 TO 700 702 TO 724 727 TO 729 731 TO 741 744 TO 750 -
752 TO 758 760 TO 766 768 TO 774 777 TO 786 789 TO 808 811 TO 820 823 TO 842 -
845 TO 853 856 TO 872 875 TO 883 886 TO 892 894 TO 900 902 TO 908 910 TO 916 -
[illegible] 933 936 TO 966 969 TO 983 986 TO 1016 1019 TO 1033 1036 TO 1042 1044 -
[illegible] 050 1052 TO 1058 1060 TO 1066 418 TO 424
JOINT RELEASES
 203 217 225 409 417 425 559 567 759 767 893 901 909 1043 1051  -
1051 1059 MOMENT Y MOMENT X
551 580 601 630 651 680 701 730 751 MOMENT X
GENER 16 ELEMENT ID 1 1 FROM 1 2 TO 51 2 TO 53 2 TO 3 2 TO 34 1 TO 52 2 TO -
35 1 TO 2 2
MODIFY [illegible] ID 16 FROM 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50
GENER 2 ELEMENT ID 129 1 FROM 401 2 TO 446 2 TO 448 2 TO 403 2 TO 434 1 TO -
447 2 TO 435 1 TO 402 2
MODIFY 1 ID 10 FROM 45 TO 34 TO 34 TO 45 TO 34 TO 34 TO 34 TO 45
GENER 2 ELEMENTS ID 131 1 FROM 417 2 TO 451 2 TO 453 2 TO 419 2 TO 437 1 TO -
452 2 TO 438 1 TO 418 2
MODIFY 1 ID 10 FROM 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34
GENER 2 ELEMENT ID 149 1 FROM 480 2 TO 513 2 TO 515 2 TO 482 2 TO 502 1 TO -
514 2 TO 503 1 TO 481 2
MODIFY 1 ID 8 FROM 33 TO 30 TO 30 TO 33 TO 30 TO 30 TO 30 TO 33
GENER 5 ELEM ID 151 1 FROM 485 2 TO 518 2 TO 520 2 TO 487 2 TO 505 1 TO 519 -
2 TO 506 1 TO 486 2
MODIFY 1 ID 8 FROM 33 TO 41 TO 41 TO 33 TO 30 TO 41 TO 30 TO 33
ELEM 156 INCID    499 529 531 501 511 530 512 500
ELEM 164 INCID    529 573 575 531 541 574 542 530
GENER 16 ELEM ID 165 1 FROM 543 2 TO 593 2 TO 595 2 TO 545 2 TO 576 1 TO 594 -
2 TO 577 1 TO 544 2
MODIFY 3 ID 16 FROM 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50
GENER 2 ELEM ID 229 1 FROM 743 2 TO 788 2 TO 790 2 TO 745 2 TO 776 1 TO 789 -
2 TO 777 1 TO 744 2
MODIFY 1 ID 10 FROM 45 TO 34 TO 34 TO 45 TO 34 TO 34 TO 34 TO 45
GENER 8 ELEM ID 231 1 FROM 759 2 TO 793 2 TO 795 2 TO 761 2 TO 779 1 TO -
[illegible] 2 TO 780 1 TO 760 2
MODIFY 1 ID 10 FROM 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34
GENER 2 ELEM ID 249 1 FROM 822 2 TO 855 2 TO 857 2 TO 824 2 TO 844 1 TO -
856 2 TO 845 1 TO 823 2
MODIFY 1 ID 8 FROM 33 TO 30 TO 30 TO 33 TO 30 TO 30 TO 30 TO 33
GENER 2 ELEM ID 251 8 FROM 827 33 TO 860 41 TO 862 41 TO 829 33 TO 847 30 -
TO 861 41 TO 848 30 TO 828 33
GENER 5 ELEM ID 252 1 FROM 833 2 TO 863 2 TO 865 2 TO 835 2 TO 849 1 TO -
864 2 TO 850 1 TO 834 2
MODIFY 1 ID 8 FROM 30 TO 44 TO 44 TO 30 TO 30 TO 44 TO 30 TO 30
GENER 16 ELEM ID 265 1 FROM 885 2 TO 935 2 TO 937 2 TO 887 2 TO 918 1 TO -
936 2 TO 919 1 TO 886 2
MODIFY 2 ID 16 FROM 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50
ELEMENT PROP
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GTSTRUDL input file for slabs with fixed supports--concluded

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UNITS INCHES
CONSTANTS
E 3120. ALL
POISSON .17 ALL
CTE .000006 ALL
UNITS FEET
LOADING 1
ELEMENT LOADS
1 TO 312 SURF FORCE PZ -1.4125
JOINT LOADS
405 747 547 889 FORCE Z -24.1
407 749 549 891 FORCE Z -58.5
409 751 551 893 411 753 553 895 413 755 555 897 -
415 757 557 899 FORCE Z -68.8
417 559 759 901 FORCE Z -34.4
829 903 907 833 FORCE Z -9.5
862 906 863 831 FORCE Z -20.
495 569 573 499 FORCE Z -7.5
571 497 FORCE Z -21.
528 529 FORCE Z -14.
UNITS INCHES
STIFFNESS ANALYSIS
LIST DISPLACE ALL
LIST STRESSES ALL
LIST ELEMENT FORCES ALL
LIST REACTIONS ALL
SAVE DIRECT 'DRSLAB'
FINISH
```

Slabs with Elastic Spring Supports

5. The GTSTRUDL input file for slabs with elastic spring supports is [illegible] this and the following pages.

```
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UNITS FEET KIPS
TYPE PLATE BENDING
GENER 33 JOINT ID 1 1 X 0. 0. Y LIST 0. 2.875 5.75 8.625 11.5 13.25 -
 15. 17.5 20. 22.5 25. 27.5 30. 32.5 35. 37.5 40. 43.5 47. 49.5 52. -
 54.25 56.5 58.25 60. 62.5 65. 67. 69. 71. 73. 74.5 76. SUP
MODIFY 4 ID 50 X 5. Y 0.
GENER 33 JOINT ID 251 1 X 25.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 -
13.25 15 17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 43.5 47 49.5 52 -
54.25 56.5 58.25 60 62.5 65 67 69 71 73 74.5 76. SUP
MODIFY 3 ID 50 X 5.5 Y 0.
GENER 17 JOINT ID 34 1 X 2.5 0. Y LIST 0. 5.75 11.5 15 20 25 30 35 -
 40 47 52 56.5 60 65 69 73 76 SUP
MODIFY 3 ID 50 X 5. Y 0.
GENER 17 JOINT ID 234 1 X 22.75 0. Y LIST 0. 5.75 11.5 15 20 25 30 -
35 40 47 52 56.5 60 65 69 73 76 SUP
MODIFY 3 ID 50 X 5.5 Y 0.
GENER 2[illegible] JOINTS ID 446 1 X 47.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 40. -
43.5 47 49.5 52. 54.25 56.5 58.25 60 62.5 65 67 69 71 73 74.5 76 SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 12 JOINTS ID 434 1 X 44.75 0 Y LIST 0 5.75 11.5 40 47 52 56.5 60 -
65 69 73 76. SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 19 JOINTS ID 513 1 X 58.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 40. -
43.5 47 49.5 52 54.25 56.5 58.25 60 62.5 65 73 74.5 76 SUP
GENER 11 JOINTS ID 502 1 X 55.75 0. Y LIST 0. 5.75 11.5 40 47 52 56.5 60 65 -
73  76 SUP
MODIFY 1 ID 30 X 5.5 Y 0.
GENER 33 JOINTS ID 543 1 X 64. 0 Y LIST 0. 2.875 5.75 8.625 11.5 13.25 15 -
17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 43.5 47 49.5 52 54.25 56.5 58.25 -
60 62.5 65 67 69 71 73 74.5 76 SUP
MODIFY 4 ID 50 X 5.25 Y 0.
GENER 17 JOINTS ID 576 1 X 66.625 0 Y LIST 0. 5.75 11.5 15 20 25 30 35 40 -
47 52 56.5 60 65 69 73 76 SUP
MODIFY 3 ID 50 X 5.25 Y 0.
GENER 22 JOINTS ID 788 1 X 90.5 0. Y LIST 0. 2.875 5.75 8.625 11.5 40. 43.5 -
47 49.5 52. 54.25 56.5 58.25 60. 62.5 65 67 69 71 73 74.5 76 SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 12 JOINTS ID 776 1 X 87.75 0. Y LIST 0. 5.75 11.5 40 47 52 56.5 60 -
65 69 73 76 SUP
MODIFY 1 ID 34 X 5.5 Y 0.
GENER 19 JOINTS ID 855 1 X 101.5 0. Y LIST 0 2.875 5.75 8.625 11.5 40 43.5 -
47 56.5 58.25 60 62.5 65 67 69 71 73 74.5 76 SUP
GENER 11 JOIN ID 844 1 X 98.75 0. Y LIST 0 5.75 11.5 40 47 56.5 60 65 69 73 -
76 SUP
MODIFY 1 ID 30 X 5.5 Y 0.
GENER 33 JOINTS ID 885 1 X 107. 0. Y LIST 0. 2.875 5.75 8.625 11.5 13.25 15 -
17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 43.5 47 49.5 52 54.25 56.5 58.25 60 -
62.5 65 67 69 71 73 74.5 76 SUP
MODIFY 3 ID 50 X 5.333 Y 0.
GENER 17 JOINTS ID 918 1 X 109.666 0. Y LIST 0. 5.75 11.5 15 20 25 30 35 40 -
47 52 56.5 60 65 69 73 76 SUP.
MODIFY 2 ID 50 X 5.333 Y 0.
STATUS FREE 35 TO 49 52 TO 82  85 TO 99 102 TO 132 135 TO 149 152 TO 182 -
185 TO 199 202 TO 208 210 TO 216 218 TO 224 226 TO 232 236 TO 249 252 TO 282 -
285 TO 299 302 TO 332 335 TO 349 352 TO 382 385 TO 399 402 TO 408 410 TO 416 -
  426 TO 432 435 TO 444 447 TO 466 469 TO 478 481 TO 500 503 TO 511 -
514 TO 530 533 TO 541 544 TO 550 552 TO 558 560 TO 566 568 TO 574 577 TO 579 -
581 TO 591 594 TO 600 602 TO 624 627 TO 629 631 TO 641 644 TO 650 652 TO 674 -
677 TO 679 681 TO 691 694 TO 700 702 TO 724 727 TO 729 731 TO 741 744 TO 750 -
752 TO 758 760 TO 766 768 TO 774 777 TO 786 789 TO 808 811 TO 820 823 TO 842 -
846 TO 853 856 TO 872 875 TO 883 886 TO 892 894 TO 900 902 TO 908 910 TO 916 -
919 TO 933 936 TO 966 969 TO 983 986 TO 1016 1019 TO 1033 1036 TO 1042 1044  -
```

GTSTRUDL input file for slabs with elastic spring supports--continued

```
TO 1060 1052 TO 1058 1060 TO 1066 418 TO 424
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1 33 KFZ 8690.
2 TO 4 KFZ 9871. KMY 749480.
5 7 25 KFZ 9871. KMY 553960.
6 24 31 KFZ 8129. KMY 456200.
8 TO 16 20 26 KFZ 11613. KMY 651720.
17 19 KFZ 13935. KMY 782100.
18 KFZ 16258. KMY 912400.
21 KFZ 11032. KMY 589500.
22 27 KFZ 10451. KMY 558450.
23 28 TO 30 KFZ 9290. KMY 521400.
32 KFZ 6968. KMY 391000.
50 83 150 350 KFZ 13335. KMX 1280100.
100 133 183 200 809 KFZ 13333. KMX 1843700.
233 575 1017 1034 KFZ 14000. KMX 1935800.
250 512 531 542 821 843 KFZ 14666. KMX 202800.
283 300 383 445 467 479 501 854 873 884 KFZ 14666. KMX 1408100.
333 592 625 642 675 692 725 742 KFZ 14000. KMX 1344100.
400 KFZ 16000. KMX 1536100.
433 KFZ 15333. KMX 1472100.
775 KFZ 13000. KMX 1248100.
787 KFZ 12000. KMX 1659300.
917 934 967 984 KFZ 14440. KMX 1386600.
1067 KFZ 7120. KMX 983400.
34 51 84 101 334 KFZ 11520. KMX 3394000.
134 151 184 KFZ 11520. KMX 3643800.
201 301 KFZ 12096. KMX 3826000.
234 251 284 KFZ 12672. KMX 4008200.
351 434 446 468 480 502 513 532 810 822 844 855 874 KFZ 12672. KMX 3733400.
384 KFZ 13824. KMX 4072800.
401 KFZ 13248. KMX 3903000.
543 KFZ 12348. KMX 3648500.
578 593 626 643 676 693 726 KFZ 12096. KMX 3563700.
743 KFZ 11232. KMX 3309100.
776 KFZ 10368. KMX 3054600.
788 KFZ 11520. KMX 3394000.
805 KFZ 12478. KMX 3676400.
918 935 968 985 1018 KFZ 12300. KMX 3624800.
1035 KFZ 6128. KMX 1806000.
209 217 225 409 417 425 559 567 759 767 893 901 909 1043 1051 1059 -
 KFZ 8424. KMX 16177000. KMY 16177000.
551 580 730 751 KFZ 8424. KMX 16177000.
601 701 KFZ 11438. KMX 14155000.
630 680 KFZ 13584. KMX 14155000.
651 KFZ 15717. KMX 14155000.
UNITS FEET
GENER 16 ELEMENT ID 1 1 FROM 1 2 TO 51 2 TO 53 2 TO 3 2 TO 34 1 TO 52 2 TO -
35 1 TO 2 2
MODIFY 7 ID 16 FROM 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50
GENER 2 ELEMENT ID 129 1 FROM 401 2 TO 446 2 TO 448 2 TO 403 2 TO 434 1 TO -
447 2 TO 435 1 TO 402 2
MODIFY 1 ID 10 FROM 45 TO 34 TO 34 TO 45 TO 34 TO 34 TO 34 TO 45
GENER 8 ELEMENTS ID 131 1 FROM 417 2 TO 451 2 TO 453 2 TO 419 2 TO 437 1 TO -
452 2 TO 438 1 TO 418 2
MODIFY 1 ID 10 FROM 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34
GENER 2 ELEMENT ID 149 1 FROM 480 2 TO 513 2 TO 515 2 TO 482 2 TO 502 1 TO -
514 2 TO 503 1 TO 481 2
MODIFY 1 ID 8 FROM 33 TO 30 TO 30 TO 33 TO 30 TO 30 TO 30 TO 33
GENER 5 ELEM ID 151 1 FROM 485 2 TO 518 2 TO 520 2 TO 487 2 TO 505 1 TO 519 -
2 TO 506 1 TO 486 2
MODIFY 1 ID 8 FROM 33 TO 41 TO 41 TO 33 TO 30 TO 41 TO 30 TO 33
ELEM 156 INCID    499 529 531 501 511 530 512 500
```

(GTSTRUDL input file for slabs with elastic spring supports--concluded

```
ELEM 164 INCID    529 573 575 531 541 574 542 530
GENER 16 ELEM ID 165 1 FROM 543 2 TO 593 2 TO 595 2 TO 545 2 TO 576 1 TO 594 -
2 TO 577 1 TO 544 2
MODIFY 3 ID 16 FROM 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50
GENER 2 ELEM ID 229 1 FROM 743 2 TO 788 2 TO 790 2 TO 745 2 TO 776 1 TO 789 -
2 TO 777 1 TO 744 2
MODIFY 1 ID 10 FROM 45 TO 34 TO 34 TO 45 TO 34 TO 34 TO 34 TO 45
GENER 8 ELEM ID 231 1 FROM 759 2 TO 793 2 TO 795 2 TO 761 2 TO 779 1 TO -
794 2 TO 780 1 TO 760 2
MODIFY 1 ID 10 FROM 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34 TO 34
GENER 2 ELEM ID 249 1 FROM 822 2 TO 855 2 TO 857 2 TO 824 2 TO 844 1 TO -
856 2 TO 845 1 TO 823 2
MODIFY 1 ID 8 FROM 33 TO 30 TO 30 TO 33 TO 30 TO 30 TO 30 TO 33
GENER 8 ELEM ID 251 8 FROM 827 33 TO 860 41 TO 862 41 TO 829 33 TO 847 30 -
TO 861 41 TO 848 30 TO 828 33
GENER 5 ELEM ID 252 1 FROM 833 2 TO 863 2 TO 865 2 TO 835 2 TO 849 1 TO -
864 2 TO 850 1 TO 834 2
MODIFY 1 ID 8 FROM 30 TO 44 TO 44 TO 30 TO 30 TO 44 TO 30 TO 30
GENER 16 ELEM ID 265 1 FROM 885 2 TO 935 2 TO 937 2 TO 887 2 TO 918 1 TO -
936 2 TO 919 1 TO 886 2
MODIFY 2 ID 16 FROM 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50 TO 50
ELEMENT PROP
1 TO 312 TYPE 'IPBQQ' THICK 2.75
UNITS INCHES
CONSTANTS
E 3120. ALL
POISSON .17 ALL
CTE .000006 ALL
UNITS FEET
LOADING 1
ELEMENT LOADS
1 TO 312 SURF FORCE PZ -1.4125
JOINT LOADS
405 747 547 889 FORCE Z -24.1
407 749 549 891 FORCE Z -58.5
409 751 551 893 411 753 553 895 413 755 555 897 -
415 757 557 899 FORCE Z -68.8
417 659 759 901 FORCE Z -34.4
829 903 907 833 FORCE Z -9.5
862 906 863 831 FORCE Z -20.
495 569 573 499 FORCE Z -7.5
571 497 FORCE Z -21.
528 529 FORCE Z -14.
UNITS INCHES
STIFFNESS ANALYSIS
LIST DISPLACE ALL
LIST STRESSES ALL
LIST ELEMENT FORCES ALL
LIST REACTIONS ALL
PLOT DEVICE SCOPE 4014 BAUD 120
PLOT PROJECT ROTATE Z -30. Y 0. X -70.
LABEL NODES
END
PLOT PROJECT D 1 M FR .1 ROTATE Z -30. Y 0. X -70.
END
FINISH
```

APPENDIX B: THEORETICAL RESULTS FOR THE SIMPLY SUPPORTED PLATE

1. Calculation of theoretical deflections and moments for a simply supported slab considering shear deflections are given on this page, for plate having the following dimensions and loads;

$$a = 20 \text{ ft}$$
$$h = 2 \text{ ft}$$
$$P = 1 \text{ ksf}$$

2. Using the following coefficients by Salerno and Goldberg,*: for $h/a = 0.1$, $b/a = 1.0$

$$\alpha = 0.04437 \qquad \bar{\alpha} = 0.04632$$
$$\bar{\beta} = 0.0481 \qquad \bar{\beta}_1 = 0.0481$$

for $\nu = 0.3$ Timoshenko's** coefficient (TC) = 0.00406.

3. Correcting for different Poisson's Ratio:

$$\Delta = \frac{0.04632}{0.04437}(0.00406)\frac{Pa^4}{\left[\dfrac{Eh^3}{12(1-\nu^2)}\right]} = (0.004238)\frac{(1)(20)^4(12)(1-0.17^2)}{(3120 \times 144)(2)^3}$$
$$= 0.002199 \text{ ft}$$
$$= 0.02638 \text{ in.}$$

$$\left(M_y\right)_{max} = \bar{\beta}_1 Pa^2 = 0.0481(1)(20)^2 = 19.24 \text{ kip-ft/ft}$$

Since M_x and M_y are equal at the plate center,

$$\left(M_x\right)_{max} = 19.24 \text{ kip-ft/ft}$$

(This moment does not take into account differences due to the actual $\nu = 0.17$ and Timoshenko's $\nu = 0.30$)

* V. L. Salerno and M. A. Goldberg. 1960 (Mar). "Effect of Shear Deformations on the Bending of Rectangular Plates," American Society of Mechanical Engineers.

** S. Timoshenko and S. Woinowsky-Krieger. 1959. Theory of Plates and Shells, 2d ed., McGraw-Hill, New York.

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	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
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Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982

(Continued)

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Instruction Report K-83-5	User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
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Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, *Concrete General* Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1384
Technical Report ATC-86-5	Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987

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